Pacific States Marine Fisheries Commission

WHITE STURGEON
MANAGEMENT FRAMEWORK PLAN

September 1992

Prepared by the

White Sturgeon Planning Committee

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Pacific States Marine Fisheries Commission

The goal of the Commission is "to promote and support policies and actions directed at the conservation, development, and management of fishery resources of mutual concern to member states though a coordinated regional approach to research monitoring and utilization."

ACKNOWLEDGEMENT

The Commission wishes to acknowledge the extensive contribution of the biologists who worked on this document. Their devotion to the resource and this plan made it all possible. The Commission is also grateful to Mr. Tom Kisanuki, USFWS, Arcata, California who transformed a very rough draft into a form the committee could address. The cover art was drawn by Mr. Calvin Sprague, USFWS, Cook, Washington.

SPORT FISH RESTORATION

This document was supported in part through funding provided by Federal Aid in Sport Fish Restoration administrative funds, Project No. 14-16-0009-90-1210, administered by the U.S. Fish and Wildlife Service.

FIGURES

TABLES

ABBREVIATIONS AND ACRONYMS

A	total annual mortality
BCMEP	British Columbia Ministry of Environment and Parks
°C	degrees Celsius
CDFG	California Department of Fish and Game
cfs	cubic feet per second
cm	centimeters
cm/s	centimeters per second
CPUE	catch per unit effort
CRITFC	Columbia River Inter-Tribal Fish Commission
dkm	dekameters
DDD	dichloro-diphenyl-dichloroethane
DDE	dichloro-diphenyl-ethylene
DDT	dichloro-diphenyl-trichloroethane
E	exploitation
°F	degrees Fahrenheit
F	instantaneous fishing mortality rate
FL	fork length
ft/s	feet per second
ft	feet
g	grams
hr	hours
ha	hectares
IDFG	Idaho Department of Fish and Game
in	inches
l	liters
lb	pounds
kg	kilograms
km	kilometers
m	meters
M	instantaneous natural mortality rate
mg	milligrams
ml	milliliters

mm	millimeters
MDFWP	Montana Department of Fish, Wildlife and Parks
NMFS	National Marine Fisheries Service
ODFW	Oregon Department of Fish and Wildlife
OSU	Oregon State University
OSY	optimal sustained yield
OTC	oxytetracycline
oz	ounces
PCB	polychlorinated biphenyls
pers. commun.	personal communication
PIT (tag)	passive integrated transponder tag
ppb	parts per billion
pm	parts per million
ppt	parts per thousand
PSMFC	Pacific States Marine Fisheries Commission
RM	river mile
s	seconds
SMTF	Sturgeon Management Task Force
sp.	species
t	metric tons
TL	total length
UCD	University of California at Davis
UOI	University of Idaho
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
WDE	Washington Department of Ecology
WDF	Washington Department of Fisheries
WDW	Washington Department of Wildlife
WSIV	white sturgeon iridovirus
WSPC	White Sturgeon Planning Committee
YIN	Yakima Indian Nation
Z	instantaneous rate of mortality

PREFACE

This white sturgeon management and research framework is a working tool for fisheries managers in the Pacific states. If there are omissions or inaccuracies, the data were unavailable, unpublished, or unfamiliar to the committee and writers. If you have information that is not represented in this document, please submit it to the Pacific States Marine Fisheries Commission in a summarized form with complete citations for future revisions of this document.

White Sturgeon Planning Committee
September 1992

EXECUTIVE SUMMARY

Historically, white sturgeon were found in streams with access to the ocean from the Aleutian Islands to central California. Their range has become more restricted due to a number of factors. Spawning populations exist in the Sacramento-San Joaquin, Columbia, and Fraser River systems. Some populations have become landlocked due to the construction of dams. While some white sturgeon use marine environments, marine environments are not obligatory for completing their life cycles. There may be as many as 18 landlocked populations of white sturgeon. Tag recoveries indicate that some sturgeon may use more than one river on the West Coast during different portions of their lives.

Male sturgeon may mature as young as 10-12 years of age, while females may not mature until 15-32 years. Females produce 0.1 million to 7 million eggs per spawning, depending on fish size and age. Spawning frequency for females has been estimated at 2-11 years; male spawning frequency is unknown. Spawning occurs between February and July, depending on water temperature and river flow. Water velocity, water temperature, and substrate size appear to influence spawning behavior and relative success.

Sturgeon eggs hatch in 7-14 days, depending on water temperature. Larvae are planktonic and disperse downstream after hatching and then actively seek cover in the substrate. Active feeding occurs about 12 days after hatching; metamorphosis is complete within approximately 20-30 days. White sturgeon grow 7-12 inches during their first full year of life; early growth is highly variable.

Juvenile sturgeon appear to use a wide variety of habitats during the year. Adults may move seasonally, perhaps in response to fluctuating food availability.

Mortality is probably high during the first five years of life. While there are no empirical data, some authors use mortality rates of 0.99 or higher from egg to age 1 in modeling efforts. Estimates of mortality after this period are highly variable, but are much lower. Estimates of sustainable exploitation rates (u) range from 0.05 to 0.57. All higher estimated rates, however, are predicated on implementation of very restrictive size limits.

Disease is an important source of mortality for artificially reared sturgeon. Newly identified viruses have become a major concern, inhibiting transfer of sturgeon among drainages and release of hatchery-reared fish into the wild. The importance of diseases and parasites in wild populations is unknown.

Historical sturgeon habitat has been severely reduced and degraded by the construction of dams, reduction in flows, and sedimentation. These factors have undoubtedly contributed to the decline of sturgeon on a coastalwide basis. The present abundance of white sturgeon varies; numbers are thought to be depressed throughout much of its native range. Specific populations are discussed in the body of this document.

Sturgeon flesh and other products have become increasingly popular. The market for caviar is very lucrative, but limited. The sale of fingerling sturgeon has recently become important for aquaculture. Very limited commercial sturgeon fisheries are allowed, the Columbia River fishery being the most prominent.

Sturgeon management is controlled by the states, the province of British Columbia, and Native American tribes. In some cases, states and tribes co-manage areas. As the result of declining sturgeon populations, the trend in sturgeon management is to be much more conservative. Directed commercial fishing has been eliminated in most areas. The sale of sturgeon caught incidentally in non-Indian fisheries is legal in Washington and Oregon. Directed sturgeon tribal fisheries also sell sturgeon. Restrictive size limits have been imposed wherever sport or commercial fishing is allowed. Idaho, Oregon, and Washington allow only catch-and-release fishing for sturgeon in the Snake River above Clarkston, Washington. Sport anglers have demonstrated increasing interest in sturgeon, even if only catch-and-release fishing is allowed or restrictive size limits are imposed. These fisheries provide millions of dollars worth of recreation annually. Sport fishing is now the main use of sturgeon throughout the Pacific states.

The successful culture of white sturgeon in recent years has resulted in commercial ventures that grow sturgeon for sale as flesh. To date, the vast majority of the broodstock for these efforts has come from wild populations. There has been interest in trying to plant hatchery-reared juvenile sturgeon in the wild to supplement existing populations. The results of these experiments are not yet available.

A wide variety of research projects are under way on all phases of sturgeon life history and habitat use. A major multi-agency effort is ongoing in the Columbia River. The onset of artificial culture has resulted in additional research on disease and nutrition.

The White Sturgeon Planning Committee (WSPC) suggests the resource agencies and tribes adopt the following goals.

1) Establish and/or maintain viable white sturgeon populations throughout their historic range.

2) Sustain optimum and/or maximum benefit for diverse consumptive and non-consumptive uses.

3) Protect and enhance critical habitat in each management unit.

C-051969

4) Promote public awareness of the white sturgeon resource.

5) Protect the genetic integrity of local populations of white sturgeon.

These goals are further defined in specific objectives. The committee also stresses the need to more fully coordinate the research and management efforts directed to the white sturgeon resource, and provides a detailed list of additional research needs in this plan.

C-051970

INTRODUCTION

White sturgeon *(Acipenser transmontanus)* live along the Pacific coast of North America and reproduce in at least three large river systems -- the Sacramento-San Joaquin, Columbia, and Fraser rivers. Individuals may complete their life cycles in fresh water or spend a portion of their lives in brackish or marine environments.

White sturgeon support both sport and commercial fisheries. Sport fishing is the main use of the species throughout the Pacific states, where consumptive and non-consumptive sport fisheries exist. Commercial harvest targeting white sturgeon became illegal throughout most of its range in the late 1800s. Commercial harvest occurs today in several estuaries, in the Columbia River downstream from McNary Dam, and in the Fraser River downstream from Mission Bridge. Today, *most* of the commercial harvest of white sturgeon occurs incidental to treaty and non-treaty commercial salmon fisheries.

Several resource agencies requested that the Pacific States Marine Fisheries Commission (PSMFC) undertake the following tasks.

1) Summarize biological knowledge about white sturgeon.

2) Summarize the historic and present management of white sturgeon.

3) Provide a forum to develop a framework for regional management.

4) Develop a regional planning document.

This White Sturgeon Management Framework Plan is the first effort toward completing these tasks. The plan represents technical knowledge from the literature and the expertise of the PSMFC White Sturgeon Planning Committee, which has also gathered information from various coastal agencies. The White Sturgeon Management Framework Plan attempts to develop a planning and management framework broad enough to encompass the diverse needs of white sturgeon populations throughout the Pacific states.

This document *does not* provide detailed analysis for each management unit. Instead, it provides a broad view of white sturgeon resources, identifies research issues of regional importance, and suggests a framework within which individual resource agencies and Native American tribes can develop appropriate management schemes.

I. BIOLOGY

A. IDENTITY

Nomenclature

Richardson described the white sturgeon in 1863 from a specimen collected in the Columbia River near Fort Vancouver, Washington (Scott and Crossman 1973). *Acipenser aleutensis*, also described in the 1800s, is considered a white sturgeon today (Scott and Crossman 1973). Other common names for the white sturgeon include Pacific sturgeon, Oregon sturgeon, Columbia sturgeon, and Sacramento sturgeon (Scott and Crossman 1973).

Taxonomy

The order Acipenseriformes consists of two families -- Acipenseridae (sturgeon) and Polyodontidae (paddlefish). There are four genera and 23 species of sturgeon. *Acipenser* is among the oldest genera of sturgeon, evolving 400 million years ago during the upper Cretaceous Period (Scott and Crossman 1973; McEnroe and Cech 1985). There are seven species of sturgeon in North America, five from the genus *Acipenser* (Robins et al. 1980). Two closely related species of the genus *Acipenser* inhabit the Pacific coast -- the green (*A. medirostris*) and white sturgeon (Scott and Crossman 1973; Brown 1989).

Morphology

Sturgeon have a cartilaginous skeleton and persistent notochord (Scott and Crossman 1973). They have a tube-like mouth and barbels on the ventral surface of a hard snout. All *Acipenser* have five rows of bony plates (scutes) -- one dorsal, two ventral, and two lateral (Scott and Crossman 1973). Denticles make the skin feel rough between the rows of scutes.

The specific arrangement and number of scutes on the white sturgeon's steel gray body are diagnostic for the species. White sturgeon have 11-14 dorsal, 36-48 lateral, and 9-12 ventral scutes (Scott and Crossman 1973). Bajkov (1955) examined white sturgeon with seven rows of scutes. About 3% of the specimens examined displayed this characteristic and were collected downstream from Bonneville Dam, the lowermost dam on the Columbia River.

Reliable identification of green and white sturgeon is possible for young-of-the-year fish that are at least 7 in (18 cm) total length (TL). The identifying characteristics are dorsal ray counts, gill raker counts, lateral scute counts, and a ratio of snout-to-barbels and barbels-to-mouth distances (Appendix Table A1; Schreiber 1959, 1960).

White sturgeon probably locate food by olfaction, rather than vision (Brannon et al. 1987). The morphology of the white sturgeon's snout is indicative of how the fish finds food (Brannon et al. 1986). The relative position of its eyes and protractile mouth indicate vision cannot be the primary method of detecting foods at close range (Brannon et al. 1985). Foods are probably detected with chemo-receptors, electro-receptors, and barbels located on the snout. Large olfactory rosettes and taste buds are present on the four sensory barbels and on the ventral surface of the rostrum (Buddington and Christofferson 1985). Electro-receptors line the ventral surface of the snout (Brannon et al. 1987).

Several authors noted snout dimorphism in white sturgeon (Crass and Gray 1982; Brannon et al. 1986). Landlocked forms appear to have more pointed snouts than those with access to the ocean (Brannon et al. 1986). Different snout shapes in sturgeon may reflect water temperatures or other factors that individuals experience during development (Ruban and Sokolov 1986; Brannon et al. 1987). There is no evidence that dimorphism represents races or subspecies (Ruban and Sokolov 1986; Brannon et al. 1987).

The white sturgeon is the largest freshwater or anadromous fish in North America. Scott and Crossman (1973) reported the largest *authentic* record of a white sturgeon as a 1,387-lb (630 kg) fish taken from the Fraser River in 1897.

Genetic Diversity

White sturgeon populations along the Pacific coast of North America are closely related (Bartley et al. 1985; Brannon et al. 1987; Brown et al. 1990). Sacramento River Basin white sturgeon are unique genetically, but are closely related to Columbia River and Fraser River populations (Brown et al. 1990). After the last ice age, the Columbia River population probably provided the founders for the Fraser River population, based on zoogeographical evidence (Brown et al. 1990). Brown et al. (1990) described six closely related genotypes (clonal lines) in the Fraser and Columbia River systems. The small number of clonal lines found with the mitochondrial deoxyribonucleic acid (mtDNA) analysis implies a small number of females founded the present populations in the Columbia and Fraser rivers (Brown et al. 1990).

The genetic diversity of the populations sampled to date is as follows (high to low): Fraser River population, Columbia River populations upstream from Bonneville Dam, Columbia River population downstream from Bonneville Dam, Sacramento-San Joaquin River population, and the Kootenai River population (Brown 1989; Brown et al. 1990). Bartley et al. (1985) and Brannon et al. (1987) ranked the genetic diversity of white sturgeon populations differently, based on electrophoresis and smaller sample sizes. Bartley et al. (1985) found more diverse populations of sturgeon in the Columbia River than in the Fraser River and concluded that all populations with access to the ocean had higher genetic diversity than landlocked populations. The following ideas temper the apparent differences between these studies: (1) the differences in heterozygosity were relatively small; (2) both parental lines are included in the electrophoretic assessment, but are not represented in the mtDNA

Sturgeon catch is small in these three pools. An estimated 152 white sturgeon were taken in Ice Harbor and Little Goose pools during 1988 (Zinicola and Hoines 1988). Less than 10 sturgeon were caught in the Lower Monumental Pool during 1988 (Zinicola and Hoines 1988).

D. COLUMBIA RIVER BASIN UPSTREAM FROM CHIEF JOSEPH DAM

There may be eight separate populations in this reach if impoundments confine fish and create discrete populations. Distribution data are not available for many segments of the upper basin. Limited historical observations provide the presence information for the upper basin (Table 2).

Data describing the abundance, status, or productivity of these populations are sparse. Some data are available for Lake Roosevelt, Kootenay Lake, and their tributaries.

Lake Roosevelt, its Tributaries, and the Columbia River to Castlegar, British Columbia

Lake Roosevelt supports a reproducing population of white sturgeon, based on the observation of small fish. A. Setter (University of Idaho, pers. commun.) observed juvenile fish <36 in (<91 cm) TL in 1989 during an ongoing sturgeon research project. G. Leibert (National Park Service, pers. commun.) noted 16-in (41 cm) TL sturgeon in the region. These small fish are the progeny of sturgeon that spawned after the construction of Grand Coulee Dam and the filling of Lake Roosevelt (1933-1941).

Most sturgeon are found in the upstream half of the reservoir and the "river" upstream. Ultrasonic tagged sturgeon were located between Chalk Grade (near the community of Rice) and China Bar (in the Columbia River upstream from Lake Roosevelt) in 1988 (UOI, unpublished data). Most of the tagged sturgeon were found in the vicinity of Marcus Island and the confluence of the Kettle River (Figures 6, 7).

Sturgeon are moderately abundant in Lake Roosevelt compared to some other parts of the Columbia River Basin. The 1989 CPUE for setline fishing in Lake Roosevelt was about 0.008 fish/hook-hour, with a range of 0-0.083 fish/hook-hour (UOI, unpublished data). Lake Roosevelt CPUE was higher than the fish/hook-hour reported for Bonneville Pool (0.004 fish/hook-hour in 1989), The Dalles Pool (0.002 fish/hook-hour in 1988), and John Day Pool (0.001 fish/hook-hour in 1990; R. Beamesderfer, ODFW pers. commun.). It was lower than the CPUE of 0.01-0.02 fish/hook-hour reported for the Snake River in Hells Canyon during the mid-1980s (Appendix Table B5). These data may not be comparable because the Lake Roosevelt data were not meant to test the distribution of sturgeon, as in the other pools.

Table 2. Presence of white sturgeon in the mainstem Columbia River upstream from Chief Joseph Dam.

Location	Presence	Source
Chief Joseph Pool	yes	Mullan et al. 1986
Lake Roosevelt	yes	Chilcote 1986
Sanpoil R.	no[1]	G. Leibert, NPS, pers. comm.
Spokane R. to L. Falls Dam	yes	G. Leibert, NPS, pers. comm.
Kettle R. to Barstow	yes	G. Leibert, NPS, pers. comm.
Col. R. to Castlegar locks	yes	A. Setter, UOI, pers. commun.
Pend Oreille R. to Boundary Dam	?[2]	
Spokane R. upstream from Little Falls Dam	?	
Castlegar locks upstream to Hugh Keenleyside Dam	?	
to the falls at Nelson, B.C.	?	
Hugh Keenleyside Dam upstream to Revelstoke Dam	?	
Revelstoke Pool upstream to Kinabasket Lake	yes	Scott and Crossman 1973
Upstream from Duncan Dam	yes	Scott and Crossman 1973
Kootenay Lakes	?	
upstream to Duncan Dam	?	
up the Kootenai R. to Kootenai Falls	yes	Andrusak 1980

[1] The reservoir backs water up into the Sanpoil River, but the flowing water section is probably not used because it is a very shallow river.

[2] This is a very short stretch of river/reservoir, but the presence of sturgeon in the tailrace of Boundary Dam needs to be confirmed.

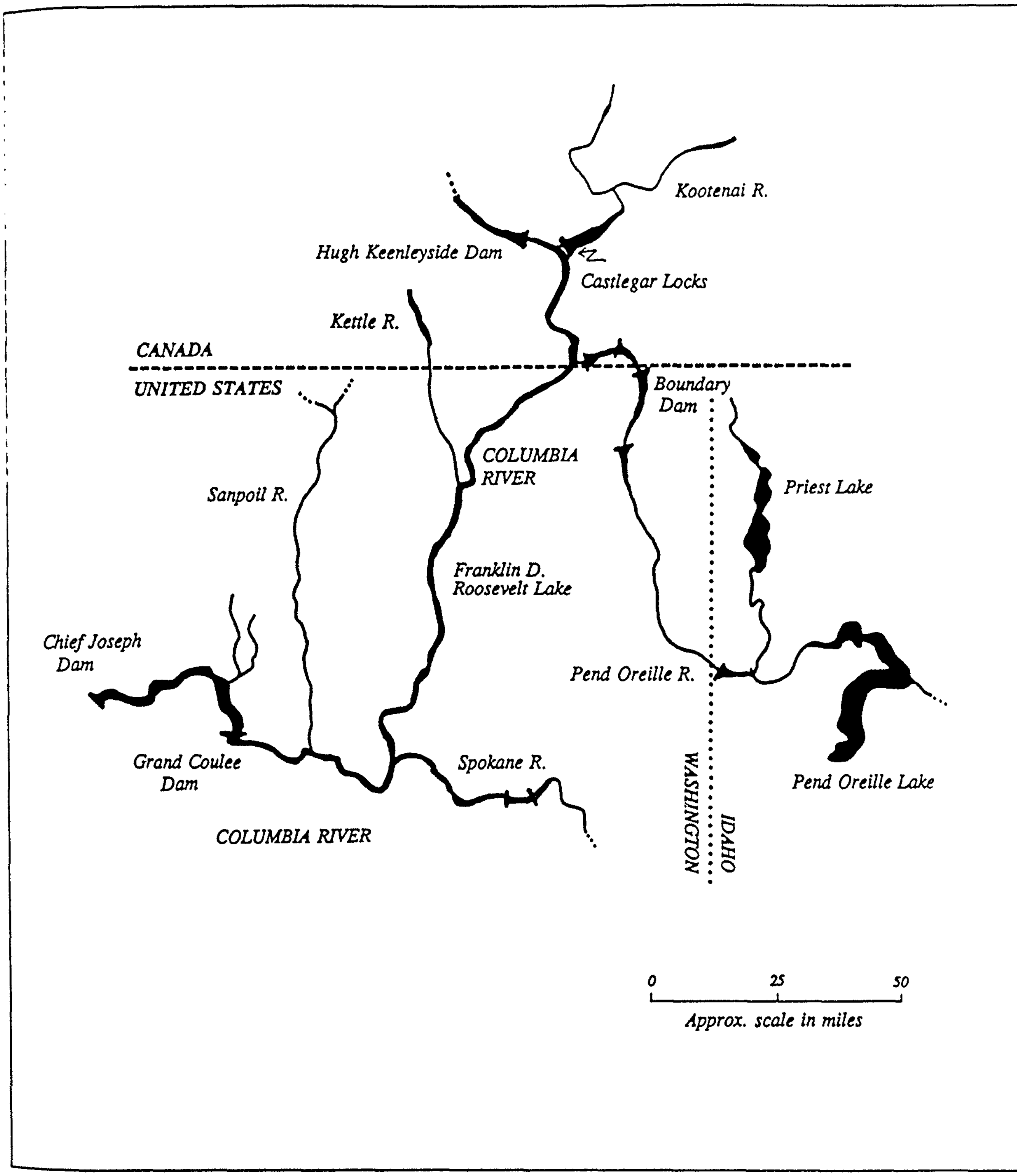

Figure 6. Map of the Columbia River Basin from Chief Joseph Dam upstream to Castlegar Locks, including Lake Roosevelt and at least part of all major tributaries.

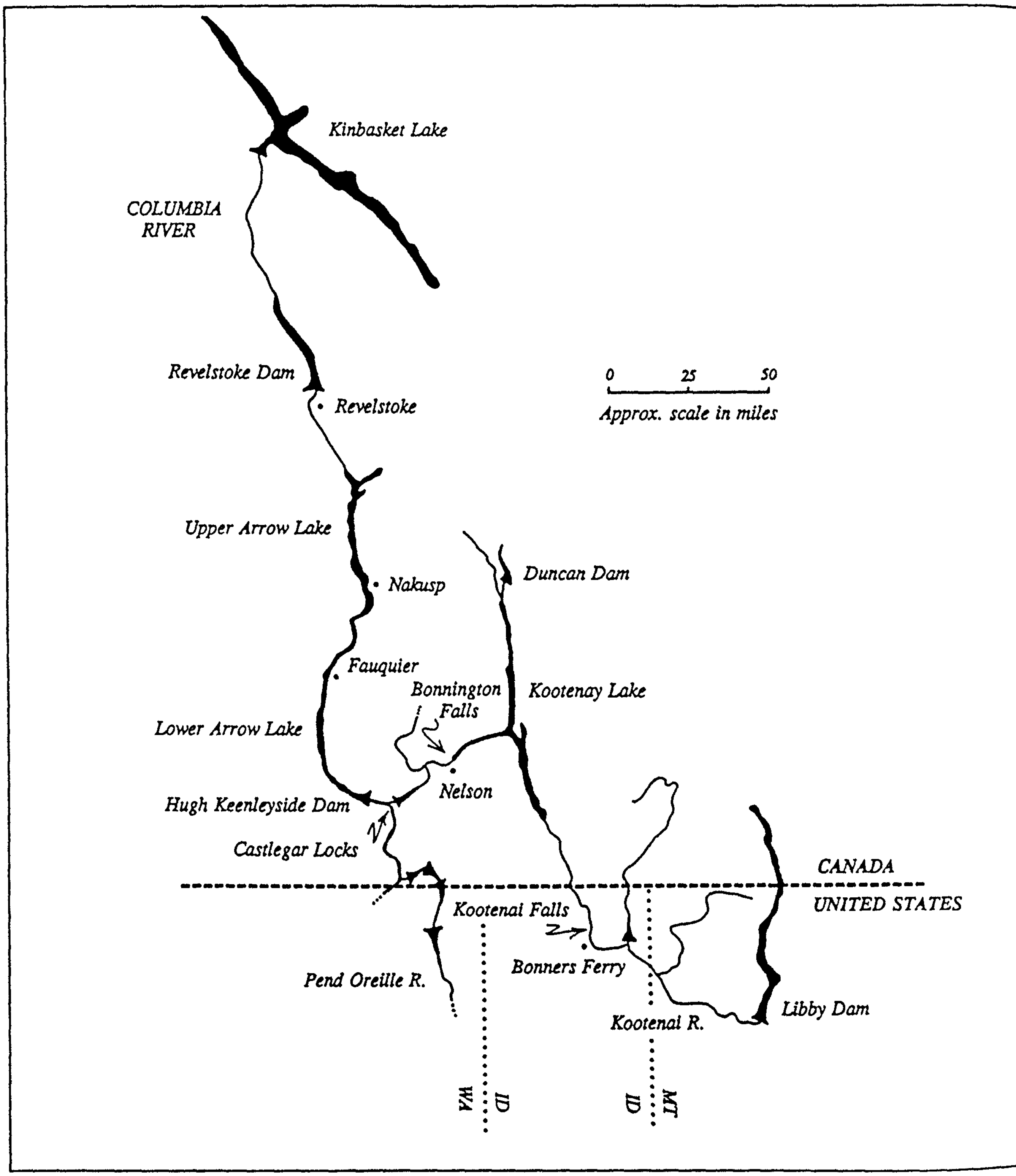

Figure 7. Map of the Columbia River Basin from Castlegar Locks to the headwaters or natural upstream limit of white sturgeon distribution.

Sportsmen actively seek sturgeon in Lake Roosevelt. For instance, in 1986 over 890 anglers were interviewed by the Coulee Dam National Recreation Area staff; this was not a structured creel census. They estimated these anglers spent at least 10,200 pole-hours seeking sturgeon (Chilcote 1986). Harvest estimates were not available for 1986. In 1988, anglers harvested an estimated 231 white sturgeon in Lake Roosevelt and the Columbia River upstream to the Canadian border (Zinicola and Hoines 1988).

Kootenay Lake and the Kootenai River

Habitat Available

White sturgeon use the portion of the Kootenai River Basin from Kootenai Falls (Montana) downstream through Idaho and into British Columbia. The river flows into the deep, oligotrophic Kootenay Lake. The outflow of Kootenay Lake passes both the Cora Linn Dam and Bonnington Falls (Apperson and Anders 1990). The geologic event creating Bonnington Falls isolated the Kootenai River and the Kootenay Lake sturgeon population from the rest of the Columbia Basin about 10,000 years ago (Apperson and Anders 1990).

Cultural development of the region altered flow regimes; confined the river channel, thus removing slough habitats; and contributed metal, chemical, and sediment pollutants. The Kootenai River is a relatively cool river (in comparison with other sturgeon habitats) with summer high temperatures of 68-72° F (20-22° C).

Distribution and Habitat Use

Sturgeon spawning sites are unknown, but may be located in Montana near Kootenai Falls (Graham 1981).

Sturgeon move between the river and the lake (Andrusak 1980; K. Apperson, IDFG, pers. commun.). K. Apperson (IDFG, pers. commun.) documented the seasonal movement of at least one tagged sturgeon between the lake and river. Andrusak (1980) indicated a portion of the British Columbia catch during the 1970s occurred in the south arm of the lake. Many fish use the shallow, relatively warm river delta (Andrusak 1980; K. Apperson IDFG, pers. commun.). Sturgeon used the main channel of the Kootenai River up to Kootenai Falls as they moved throughout the river (Partridge 1983; K. Apperson, IDFG, pers. commun.). None were found in the tributaries of the river (Partridge 1983). Apperson and Anders (1990) caught sturgeon from RM 193 near Kootenai Falls downstream to RM 75 within the river delta. Most are found downstream from the community of Bonners Ferry (Partridge 1983).

Sturgeon moved between the largest holes in the river during the summer (Apperson and Anders 1990). Within a hole, individuals remained deep in the water column and moved very little except while foraging, when they moved into shallow water (Apperson and Anders

1990). During the late summer and fall, tagged fish moved into the deepest holes in the river and into the lake (Apperson and Anders 1990).

Locations most likely to be used in the river were sites over 20 ft (6 m) deep with velocities <0.77 ft/s (<0.24 m/s) and temperatures of 57-68° F (14-20° C).

Abundance, Status, and Productivity

There is no evidence of recent reproduction by the Kootenai River white sturgeon population (Andrusak 1980; Graham 1981; Partridge 1983; Apperson and Anders 1990). Between 1977 and 1982, biologists did not catch white sturgeon <20 in (<51 cm) TL. Apperson and Anders (1990) did not capture sturgeon <43 in (<109 cm) TL.

The population may be slowly declining based on an estimate of 1,194 fish (range of 907-1,503) from the early 1980s and an estimate of 870 fish (range of 574-1,463) in 1989. Anglers caught sturgeon over 36 in (91 cm) TL at a rate of about 0.04 fish/hr in the Kootenai River (Partridge 1983). Apperson and Anders (1990) reported a slightly lower rate of 0.03 fish/hr for rod and reel biological sampling in 1989.

The mean annual growth increment of sturgeon in the size range of 43-71 in (109-180 cm) TL in the Kootenai River Basin was 1.4 in (3.6 cm) between 1988 and 1989 (Apperson and Anders 1990).

E. MAINSTEM SNAKE RIVER UPSTREAM FROM LOWER GRANITE DAM

The construction of Lower Granite Dam in 1975 created the present downstream boundary of this management unit. There are nine impoundments and, therefore, nine possible white sturgeon populations between Lower Granite Dam and Shoshone Falls (Table 3; Figure 8).

Table 3. Presence of white sturgeon in the nine regions of the Snake River between Lower Granite Dam and Shoshone Falls. Dates in parentheses indicate when projects were completed.

Location	Presence	Source
Lower Granite Pool (1975)	yes	D. Bennett, UOI, pers. commun.
Snake River to Hells Canyon Dam	yes	Lukens 1983
Salmon River	yes	Cochnauer 1983; unpublished IDFG data[1]
Grande Ronde River	yes[2]	Donaldson 1958
Clearwater River	yes	Cochnauer 1983
Hells Canyon Pool (1967)	no	Welsh and Reid 1971
Oxbow Pool (1961)	yes[3]	Welsh and Reid 1971
Brownlee Pool (1958) (and the Snake River upstream to Swan Falls Dam)	yes	Mabbott & Holubetz 1989
Swan Falls Pool (1910) (and the Snake River upstream to C.J. Strike Dam)	yes	Cochnauer 1983
C.J. Strike Pool (1952) (and the Snake River upstream to Bliss Dam)	yes	Cochnauer 1983
Bliss Pool (1950) (and the Snake River upstream to Lower Salmon Falls Dam)	yes	Cochnauer 1983
Lower Salmon Falls Pool (1949) (and the Snake River upstream to Upper Salmon Falls Dam)	yes	Cochnauer et al. 1985
Upper Salmon Falls Pool (1932) (and the Snake River upstream to Shoshone Falls[4])	yes	Cochnauer et al. 1985

[1] Nine sturgeon were reported in the Salmon River on 1989 sport log books.

C-051981

Table 3 (cont.). Presence of white sturgeon in the nine regions of the Snake River between Lower Granite Dam and Shoshone Falls.

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[2] Donaldson (1958) reported sturgeon in Wallowa Lake, which flows into the Wallowa River, a tributary of the Grande Ronde River. The Grande Ronde River flows into the Snake River between the confluence of the Salmon and Clearwater rivers. Donaldson (1958) also reported juvenile sturgeon in Catherine Creek, a tributary to the Grande Ronde River.

[3] Twenty-nine were found in the upstream end of the Oxbow Pool (Brownlee tailrace).

[4] This was the historic upper limit for anadromous fish; we assume sturgeon are not upstream, although in the Kootenai River there is a sturgeon population upstream from the historic anadromous limit.

C-051982

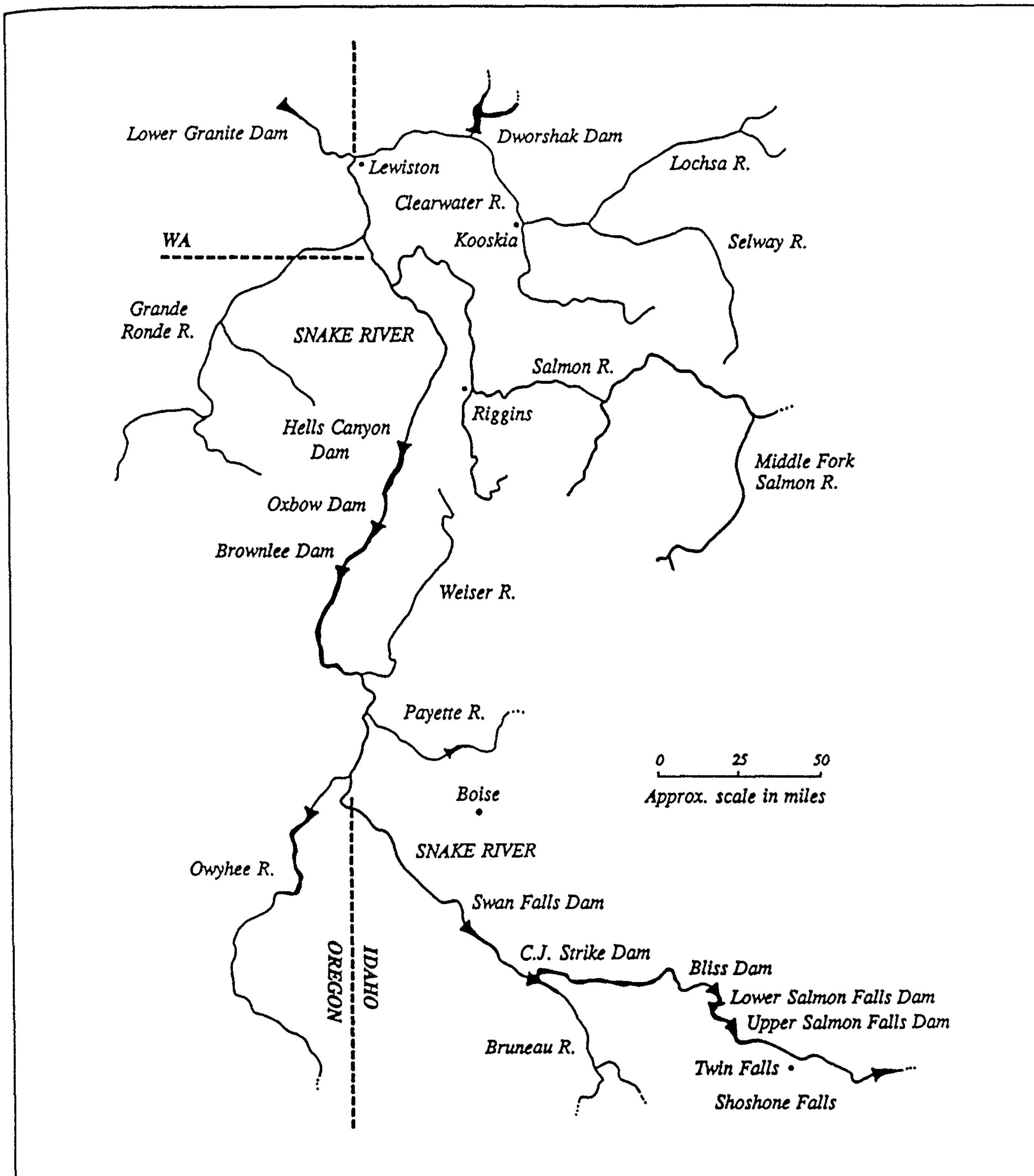

Figure 8. Map of the Snake River Basin from Lower Granite Dam to Shoshone Falls.

Lower Granite Pool and the Snake River to Hells Canyon Dam

Habitat Available

The Snake River flows 140 miles (224.5 km) between Lower Granite Dam and Hells Canyon Dam. Sturgeon in this river reach became isolated in 1975 with the completion of Lower Granite Dam. This reach includes 33 miles (53 km) of slack water in Lower Granite Reservoir and 107 miles (172 km) of free-flowing river. The reservoir extends upstream, beyond the confluence of the Snake and Clearwater rivers (at the community of Lewiston, Idaho). From Lower Granite Reservoir to the Hells Canyon tailrace, the river forms the Washington-Idaho border for 37 miles (59 km) and the Oregon-Idaho border for 71 miles (114.2 km). Near the upper end of the reservoir, the river emerges from Hells Canyon, the deepest canyon in North America. There are numerous tributaries, including the Clearwater, Salmon, Grande Ronde, and Imnaha rivers.

Impoundments upstream influence both water temperature and the annual hydrograph pattern of the free-flowing section of the Snake River. Hells Canyon Dam operates as a peaking facility, therefore the water surface elevation of the free-flowing section of river near the dam may vary 2 ft (61 cm) or more daily. The series of impoundments upstream modify the typical annual hydrograph by increasing fall, winter, and early spring flows, while reducing peak flows and extending the duration of high flows later in the spring (Coon et al. 1977). The water released from deep within the reservoir is cooler in the summer and warmer in the winter than the pre-impoundment inflow. The impoundments create more extreme daily temperature changes in the river downstream from Hells Canyon Dam (Coon et al. 1977).

Spring and summer flows at Hells Canyon Dam average 33,600 cfs (Lukens 1983). At Anatone, about 80 miles (128.4 km) downstream from Hells Canyon Dam, flows for the same period were 16,800-145,400 cfs, with a mean of 73,800 cfs (Lukens 1983). Water temperatures at Anatone ranged from 43-77° F (6-25° C) with an annual average of 58° F (14.5° C; Lukens 1983, 1985). Temperatures exceed 50° F (10° C) by mid-May, and 59° F (15° C) by mid-July (Lukens 1983).

The river gradient from Lower Granite Pool to the Wallowa Whitman National Forest boundary is 3.7 ft/mi (0.7 m/km). The upstream gradient is a constant 9.5 ft/mi (1.8 m/km) from the Wallowa Whitman National Forest border to Hells Canyon Dam. This reach of river is a series of long riffles and dispersed deep pools. The pools are generally >30 ft (>9 m) deep with strong eddies.

Distribution and Habitat Use

White sturgeon use both riverine and slack water habitats between Lower Granite and Hells Canyon dams. However, white sturgeon may not be as abundant in the slack water of Lower Granite Pool as they are in the river. Anglers caught an estimated 25 fish in Lower

Granite Pool downstream from the Idaho border in 1988 (Zinicola and Hoines 1988). Anglers reported over 300 sturgeon hooked in the river in a voluntary reporting program in 1989 (IDFG, unpublished data).

Coon et al. (1977) described the distribution of sturgeon by size group between Lower Granite and Hells Canyon dams prior to the closing of Lower Granite Dam. Small sturgeon 20-30 in (51-76 cm) TL were found throughout the river, but were not abundant between Lower Granite Dam (RM 114) and Blyton Landing (RM 120). Fish <36 in (91 cm) TL used sandy bottom holes in the river. Larger fish, 36-72 in (91-183 cm) TL, tended to use more turbulent holes in the more narrow portion of the river canyon and were most abundant near the mouth of the Salmon River (RM 188). Most of the fish >72 in (183 cm) TL used upstream areas, primarily between Johnson Bar (RM 230) and Three Creeks (RM 238). Sturgeon seemed to prefer fast moving water instead of the reservoir. Individuals (30-67 in; 76-170 cm TL) equipped with sonic tags moved just upstream from the pooled water when Lower Granite Dam was completed.

The only tributary to the Snake River that may support many sturgeon is the Salmon River. Sturgeon have not been found recently in the Grande Ronde River. At least one sturgeon was caught in the Clearwater River in recent years near the community of Peck (Cochnauer 1983).

Abundance, Status, and Productivity

Sturgeon remain relatively abundant in the Snake River between Lower Granite Reservoir and Hells Canyon Dam (Cochnauer 1983; Cochnauer et al. 1985; Lukens 1985; IDFG, unpublished data). Reproduction occurs in this reach, based on the continuing abundance of small fish (Lukens 1984; IDFG, unpublished). Retention of sturgeon by the sport fishery in the Snake River bordering Oregon and Idaho has been prohibited since 1970.

The sturgeon population size was estimated at 8,000-12,000 fish in 1972-1975 (Coon et al. 1977). About 6,880-10,320 were 18-36 in (46-91 cm) TL, 320-480 were 36-72 in (92-183 cm) TL, and 800-1,200 were >72 in (>183 cm) TL. The abundance of 36-72 in sturgeon increased after catch and release regulations had been in place for about 10 years (Lukens 1983). Mid-sized sturgeon now represent 15-18% instead of 3-4% of the population sampled in the mid-1970s (Coon et al. 1977; Lukens 1983, 1985).

Recent estimates of the population are 4,000 fish (Lukens 1983, 1985). However, Lukens (1983) cautioned against making comparisons of the 1978-1982 population estimates and those by Coon et al. (1977), citing differences in methodology.

Salmon River sturgeon anglers accounted for about 3% (31) of the recorded Idaho catch (1,033) in 1989 (IDFG, unpublished data). All sturgeon captured in Idaho must be released.

Hells Canyon Pool and Oxbow Pool

The Hells Canyon Pool extends 26 miles (41.8 km) upstream to Oxbow Dam (RM 247-273). The two largest tributaries to the pool are Indian and Pine creeks. The project, constructed in 1967, operates as a peaking facility. No estimates of abundance are available, however, Welsh and Reid (1971) stated that sturgeon are not present in this pool.

The Oxbow Pool extends 12 miles (19.3 km) upstream to Brownlee Dam (RM 285). There are no major tributaries to Oxbow Pool. The project, constructed in 1961, operates as a peaking facility. Anglers catch sturgeon in the Brownlee Dam tailrace portion of Oxbow Pool, but the species is probably not abundant (Welsh and Reid 1971).

Brownlee Pool and the Snake River Upstream to Swan Falls Dam

Habitat Available and Fish Distribution

The area between Brownlee and Swan Falls dams is the longest river reach and largest reservoir available to sturgeon between Hells Canyon Dam and Shoshone Falls.

Brownlee Dam, constructed in 1958, provides extensive water storage capacity of 980,250 acre-ft (1,208,648 cubic dkms) for the region. Steep shorelines of boulders and bedrock rim the reservoir. Although constructed for hydroelectric generation and peaking flows, the rule curve also calls for flood control operations. As a result, the water surface elevation fluctuates up to 108 ft (33 m) in some years. The reservoir is lowest early in the spring. Shoreline vegetation begins to grow in the spring and is later inundated as the reservoir reaches full pool for the recreational season. The reservoir thermally stratifies by June with a thermocline at about 148 ft (45 m). Algal blooms are common in the summer and fall. Dissolved oxygen levels decline in the upper 66 ft (20 m) of the water column to 2-3 ppm (2-3 mg/l) during September (Bennett and Dunsmoor 1986). Fall turnover occurs in late October or November (Bennett and Dunsmoor 1986). At least 28 sturgeon died in July 1990, probably due to low dissolved oxygen (T. Cochnauer, IDFG, pers. commun.)

The Snake River extends about 171 miles (275 km) between Brownlee Dam and Swan Falls Dam (RM 456). This includes about 66 miles (106 km) of reservoir environment and 105 miles (169 km) of free-flowing river habitat.

Suitable spawning habitat is available in the 53 miles (86 km) of flowing river downstream from Swan Falls Dam (Cochnauer et al. 1985). Sturgeon >72 in (>183 cm) TL made up a larger proportion of the fish hooked by anglers upstream from Walters Ferry than downstream (IDFG, unpublished data). No other sturgeon distribution data were available.

Abundance, Status, and Productivity

Historically, sturgeon were abundant in the Snake River near Walters Ferry (Cochnauer 1983). Sturgeon are still caught by anglers in this area, however, Cochnauer et al. (1985) reported sturgeon were more abundant upstream from Swan Falls Dam, as well as downstream from Hells Canyon, than in this area. Catch-per-unit-effort data for 1989 showed higher catch rates downstream from Swan Falls Dam; anglers reported 0.05-0.15 fish/angler-hr between Brownlee Dam and Swan Falls Dam, and catch rates of 0.0-0.10 fish/angler-hr upstream from Swan Falls Dam.

White sturgeon found between Brownlee and Swan Falls dams grew faster than sturgeon in other sections of the Snake River, possibly due to a combination of low abundance and good growing conditions (Cochnauer et al. 1985). The faster growth may reflect a compensatory response to low recruitment. Delayed mortality from catch-and-release fishing or poaching could have reduced sturgeon populations in the area (Cochnauer et al. 1985).

Between 1981 and 1989 the population either increased or became more catchable. Anglers caught sturgeon at a rate of 0.001 fish/hr in 1981 (Mabbot and Holubetz 1989). In 1989, punch-card data indicated the catch rate doubled (IDFG, unpublished data). Idaho Department of Fish and Game sampling caught sturgeon at a rate of 0.11 fish/hr in 1985, 0.05 fish/hr in 1987, and 0.15 fish/hr in 1989 (Reid and Mabbott 1987; Mabbott and Holubetz 1989). The 1989 angler reports indicated that <5% of the sturgeon hooked in this part of the Snake River were <36 in (<91 cm) TL (IDFG, unpublished data). In comparison, several other locations in the Snake River reported much higher proportions of small fish (>65%, 40%, and 30%; IDFG, unpublished data).

Reid and Mabbot (1987) estimated the sturgeon population size to be 135-173 fish between Swan Falls Dam and Walters Ferry, a community three miles (4.8 km) downstream from the dam. The authors suggested this is an overestimate because fish were able to move into and out of the sample area (the population was not closed).

With the exception of the dissolved oxygen problem, there were no other apparent water quality conditions influencing white sturgeon production in this reach (Cochnauer et al. 1985). Several species of fishes in Brownlee Reservoir contained higher concentrations of mercury (0.3-0.7 ppm) than fish elsewhere in the Snake River (Gebhards et al. 1971). Although sturgeon were not tested for toxins, studies in other waters (Section I.G.) show sturgeon can retain such toxins.

Swan Falls Dam to C.J. Strike Dam

From the early 1900s to 1936, Swan Falls Dam constricted, but did not span the Snake River. Today Swan Falls Dam impounds water for five miles (8 km) upstream (Cochnauer 1983). The pool has a mean depth of about 8 ft (2 m) with a 900-acre (365 ha) surface area. The project is a run-of-the-river hydropower facility. The facility provides partial re-regulation of the larger C.J. Strike project upstream.

The small population of sturgeon between Swan Falls and C.J. Strike dams is spawning-limited; fish less than 5 years old were not found (Cochnauer 1983). In addition, the population has been declining since the early 1970s (Cochnauer et al. 1985). Some recruitment may occur; small fish <36 in (<91 cm) TL represented about 20% of the sturgeon hooked by anglers in this area during 1989 (IDFG, unpublished data).

C.J. Strike Dam to Bliss Dam

Habitat Available and Fish Distribution

There are 66.3 miles (106.7 km) of river and reservoir between C.J. Strike Dam and Bliss Dam. There are three major types of habitat present -- slack water, a low gradient river, and a canyon river. The Bruneau and Big Wood drainages enter the Snake River between C.J. Strike and Bliss dams. The C.J. Strike Reservoir is 20 miles (32.2 km) long (Cochnauer 1983) and is homothermous throughout the summer (Goodnight 1972).

There are about 12 miles (19.3 km) of flowing river between the Bliss Dam tailrace (RM 560) and Clover Creek (RM 550), which is located near the community of King Hill. The river falls about 6 ft/mi (1 m/km) through a canyon (Cochnauer 1981). It is typically a fast, deep (33 ft; 10 m) run-type habitat with intermittent pools and riffles (Cochnauer 1981). There are several pools up to 49 ft (15 m) deep (Cochnauer 1983). The banks are steep with boulders and sagebrush.

The remainder of the waterway (RM 550-517) flows through relatively flat terrain with a gradient of 1.6 ft/mi (0.3 m/km; Cochnauer 1981). There are about 34 miles (54.7 km) of free-flowing, low gradient (3.2 ft/mile; 0.6 m/km) river between the C.J. Strike Pool and the canyon. The run-type habitats support abundant aquatic vegetation in the summer. There are a few pools 26-32 ft deep (8-10 m) and one pool >64 ft (20 m) deep (Cochnauer 1983).

Abundance, Status, and Productivity

Historically, many of the larger sturgeon (600-800 lb; 272-363 kg) harvested came from the Glenn's Ferry area within this region (McDonald 1894). White sturgeon are more abundant between C.J. Strike and Bliss dams than elsewhere upstream from Brownlee Dam (Cochnauer 1983). About 1,500-4,300 sturgeon 24-106 in TL (60-270 cm) live between C.J. Strike and Bliss dams (Cochnauer 1983). Sturgeon grow rapidly here (Cochnauer et al. 1985), probably because the water is generally warmer in this part of the Snake River than elsewhere.

The presence of small fish indicates reproduction occurs in this region. Over 35% of the sturgeon hooked by anglers in 1989 were <36 in (<91 cm) TL (IDFG, unpublished data). Anglers caught similar numbers of sturgeon here (362) as they did in Hells Canyon (308; IDFG, unpublished data). However, anglers also expended more effort to catch the sturgeon; the estimated CPUE was <0.1 fish/hook-hr in comparison with about 0.2-0.5 fish/hr reported in Hells Canyon (IDFG, unpublished data).

Bliss Dam to Lower Salmon Falls Dam

Bliss Dam, constructed in 1950, impounds water from the site of a natural falls upstream for approximately 5.6 miles (9 km), but slack water extends only 4.7 miles (7.6 km) upstream (Cochnauer 1983). The remaining eight miles (12.9 km) of this 12.7 miles (20.4 km) are free flowing through a canyon 400-600 ft (122-183 m) deep. Between Bliss Dam and Lower Salmon Falls, the river canyon is narrow with bedrock and rubble lining the characteristic deep pools and rapids. Sturgeon are present, but not abundant in this region (Cochnauer et al. 1985; IDFG, unpublished data). Small spawning populations, rather than limited habitat, probably limit recruitment (Cochnauer et al. 1985).

Lower and Upper Salmon Falls to Shoshone Falls

These two regions became separated from the rest of the Snake River between 1937 (Upper Salmon Falls) and 1949 (Lower Salmon Falls). Milner Dam controls the flow over Shoshone Falls. The mean annual river flow at Shoshone Falls is about 2,825 cfs, but declines essentially to zero during the irrigation season (Cochnauer 1983).

Between Shoshone Falls (natural) and the Upper Salmon Falls impoundment, the Snake River is primarily free flowing. The Upper Salmon Falls Pool is about 3.1 miles (5 km) long, representing less than 10% of this 33.6-mile (54 km) reach (Lukens 1981). The river channel flows through a 400-600 ft (122-183 m) deep canyon, and the stream gradient averages 9.8 ft/mi (1.8 m/km; Lukens 1982) forming a series of slow moving runs, deep pools, and high gradient rapids (Cochnauer 1983). There are large springs along the north bank that contribute water at a constant 57° F (14° C) temperature.

The river continues to drop through a canyon between Upper and Lower Salmon falls. The first 0.3 miles (0.5 km) of the river flow freely, but diversions remove all the water from the next river mile in a flume for power generation and irrigation. In this section, water is present only during high flows (Lukens 1981). Spring (groundwater) inflow, which is typical upstream, is not as prevalent here. The diverted section ends at the slack water impoundment formed by Lower Salmon Falls.

Sturgeon are present in low numbers between Lower and Upper Salmon falls, and the small spawning population may limit recruitment (Cochnauer et al. 1985). Sturgeon caught upstream from Upper Salmon Falls appear to grow faster than other Idaho sturgeon (Cochnauer et al. 1985). This may be an artifact as these fish may have failed to form

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annuli, due to the constant temperature of groundwater (spring) inflow and abundant food in the area.

F. FRASER RIVER

Distribution and Habitat Use

The Fraser River and its tributaries drain approximately half of the province of British Columbia (Figure 9). The Fraser River Estuary is diverse with fiord-type inlets and multiple river channels. The metropolitan areas of Vancouver, Port Moody, and Chilliwak line the shores of this region. A barrier to sturgeon migration potentially exists at Hells Gate, where there was a landslide in 1914 (Brown et al. 1990).

The sturgeon population downstream from Hells Gate has access to an extensive tidewater area. The lower Fraser River population is probably semi-anadromous, moving between the ocean and fresh water (Semakula and Larkin 1968; Dixon 1986). Some sturgeon tagged in the Fraser River tidewater region migrated along the Pacific coast to the Columbia River (Semakula 1963). This semi-anadromous population probably spawns in the vicinity between Langley and Yale (Semakula and Larkin 1968).

The landlocked population living upstream from Hells Gate uses the Fraser River at least as far upstream as the confluence of the McGregor River (D. Cadden, British Columbia Ministry of Environment and Parks, pers. commun.). There may be several landlocked sturgeon populations; there are three inland populations in the tributary watersheds of the Nechako, Stuart, and Thompson River basins (Dixon 1986). These three populations may be adfluvial in the Fraser River system, moving between large lakes and riverine environments (Dixon 1986; D. Cadden, BCMEP, pers. commun.).

Abundance, Status, and Productivity

Current estimates of white sturgeon abundance in the Fraser River system are not available. Dixon (1986) described the sturgeon population in the Nechako River system. The Nechako River sturgeon population is slow growing, and tends to be in poor condition (lighter weight) compared to other populations. Information concerning other landlocked populations in the mainstem Fraser River, Stuart River Basin, and Thompson River system is not available.

The semi-anadromous Fraser River population grows more slowly and matures later than populations in the Sacramento-San Joaquin Estuary or lower Columbia River (Appendix Table A5).

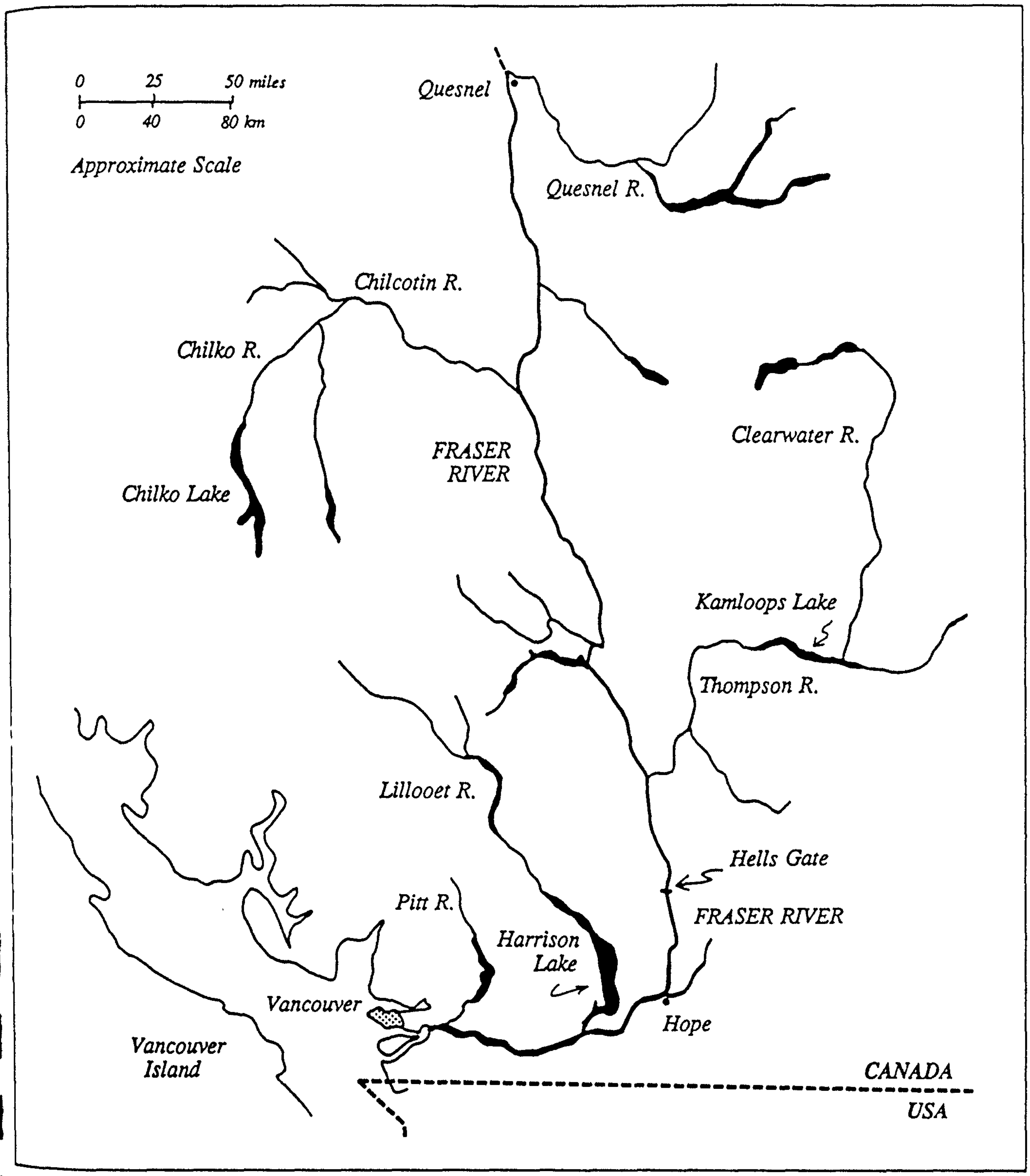


Figure 9. Map of the Fraser River Basin in British Columbia showing Hells Gate and several tributaries.

G. PACIFIC COAST AND COASTAL RIVERS

Commercial landings and tag returns indicate white sturgeon use coastal bays and estuaries along the California, Oregon, and Washington coasts (Pycha 1956; Kohlhorst et al. 1991). Tagging information demonstrates that at least some individuals move between coastal river basins. Sturgeon have been reported in several Pacific coast streams; the status of sturgeon in other streams is unknown (Figures 10, 11, 12).

This report identifies 10 potential management units:

1. California coast
2. Klamath/Trinity River Basin
3. Oregon coast
4. Rogue River Basin
5. Coos Bay
6. Umpqua River Basin
7. Yaquina River Basin
8. Tillamook/Nehalem Bay
9. Washington coast-Puget Sound
10. Canadian and Alaskan coast

White sturgeon distribution in the ocean and the amount of time spent in the ocean are unknown. Estimates of abundance are not available for marine regions. The only data available are a few tag returns from fish moving between basins. The marine population may be comprised of one or more of the following.

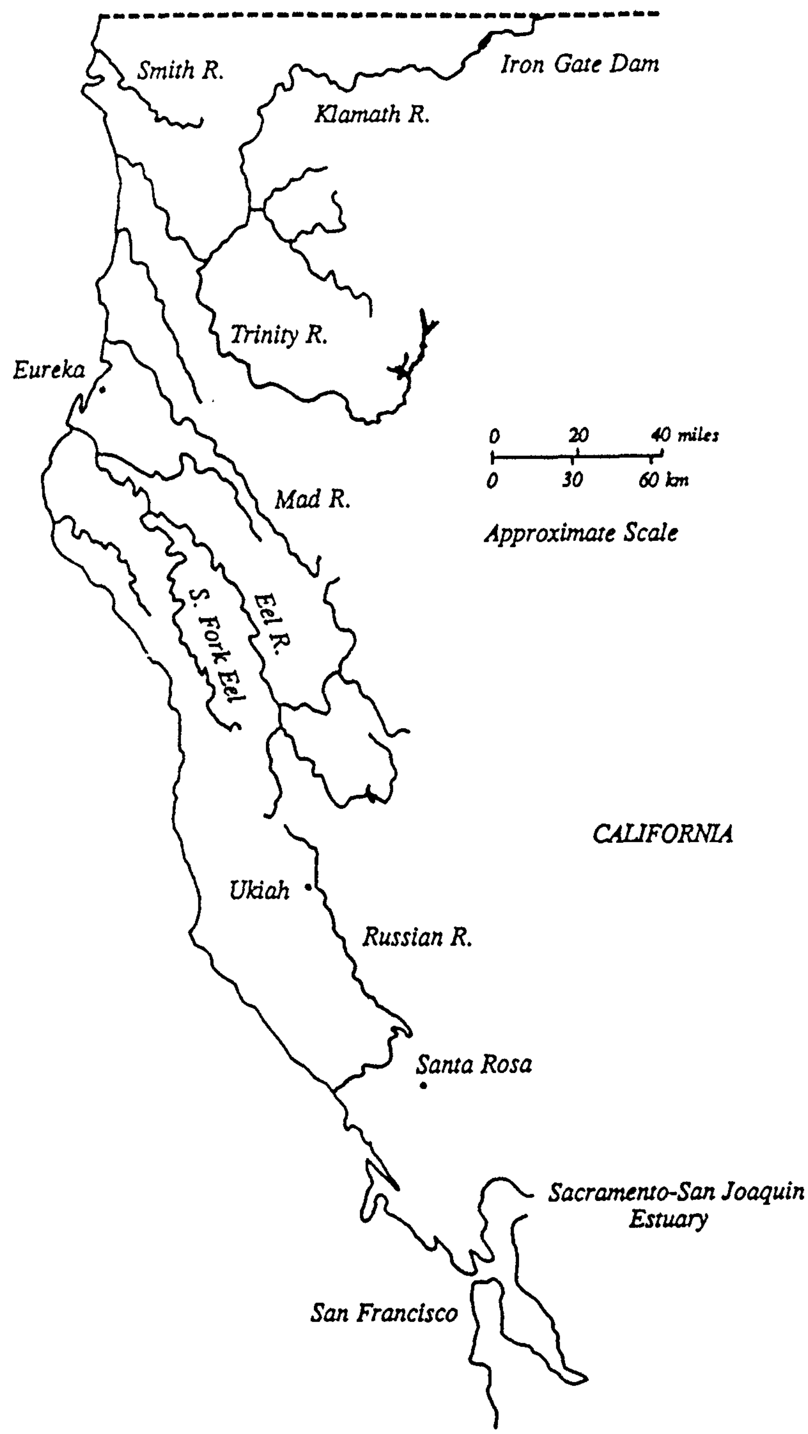
1) Individuals moving between river basins.

2) A feeding migration.

3) An anadromous period of subadult life.

California Coast

The use of the ocean by Sacramento-San Joaquin Estuary sturgeon is not well understood. Tagging studies suggest that most sturgeon never leave the estuary, although the high year-to-year variability in abundance estimates may be evidence of environmentally influenced movement between the ocean and bays. Of those that use the ocean, some individuals remain along the California coast, others move up the coast and enter rivers in Oregon (Umpqua River, Yaquina River, Tillamook Bay, and Columbia River) or Washington (Willapa Bay and River, Grays Harbor, and Chehalis River; Kohlhorst et al. 1991). Habitat, distribution, or abundance data of white sturgeon along the California coast are unavailable.



'igure 10. Map of the northern California coast identifying the major rivers.

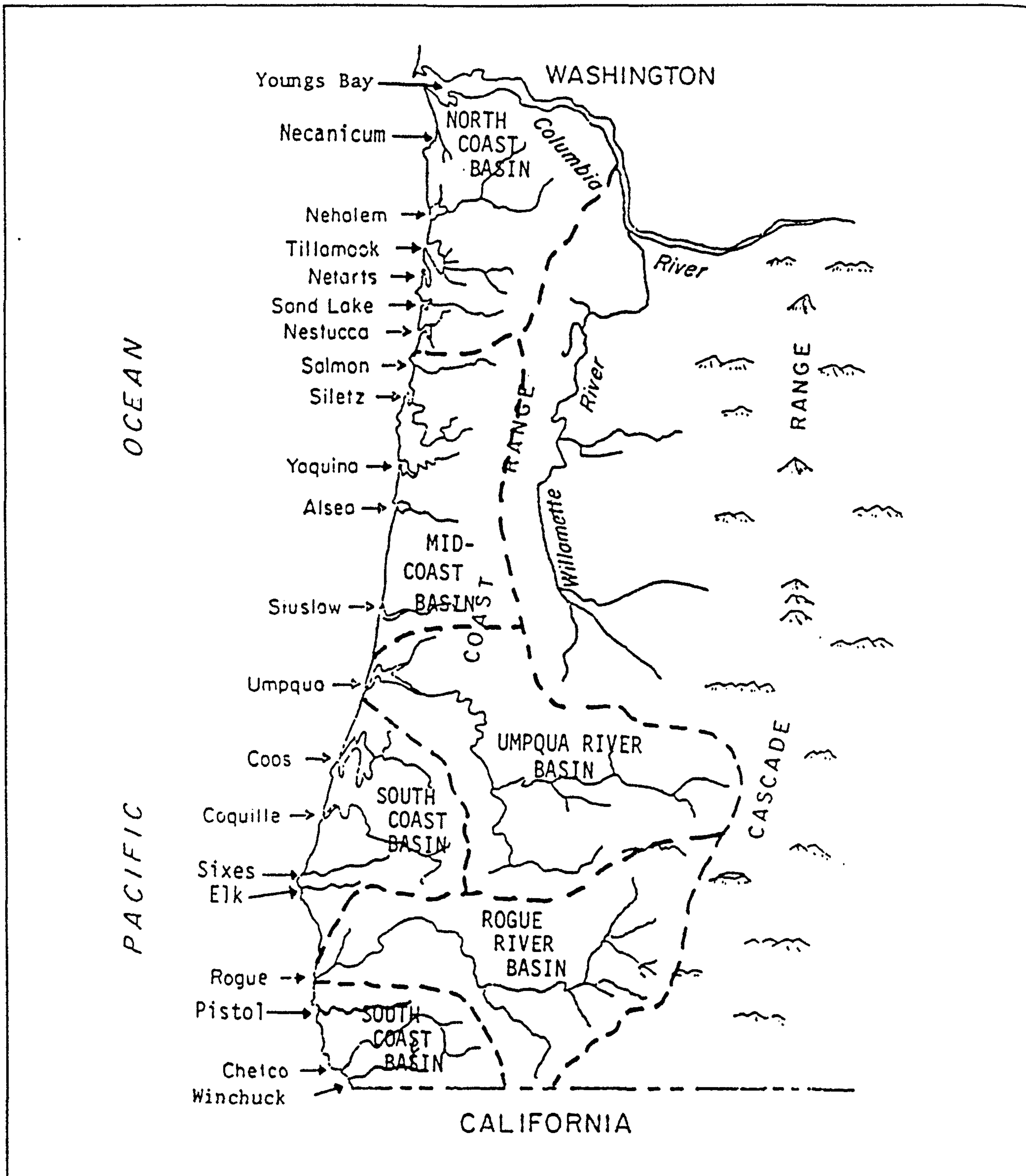


Figure 11. Map of the Oregon coast identifying the major rivers flowing into the ocean, and bay areas (adapted from Percy et al. 1974).

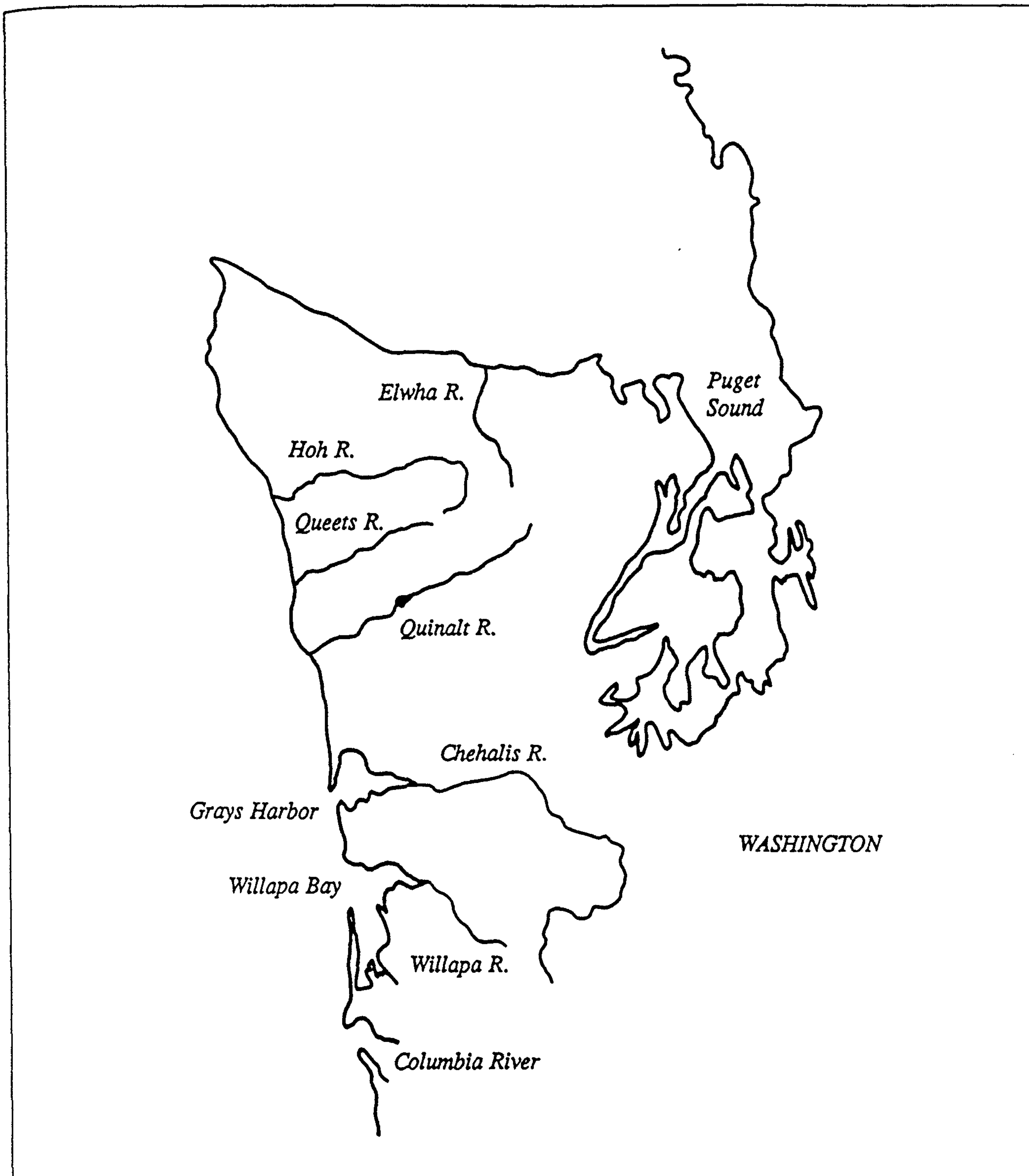


Figure 12. Map of the Washington coast and Puget Sound identifying the major rivers flowing into the ocean, and bay areas.

Klamath/Trinity River Basin (California-Oregon)

The Klamath River drains 15,440 square miles (40,400 km^2) and is free flowing for most of its length in California (Adair et al. 1984). Iron Gate Dam, located at RM 190, is the upstream limit for anadromous fish in the Klamath River. Upstream from Iron Gate Dam, there are at least five additional impoundments and a large, natural lake.

The Trinity River is the largest tributary to the Klamath River downstream from Iron Gate Dam. Lewiston Dam, at RM 155, is the upper limit for anadromous fish in the Trinity River Basin (Adair et al. 1984).

The Klamath/Trinity River system supports green and white sturgeon, but green sturgeon is the dominant species (Tuss 1989a). White sturgeon are uncommon in the Klamath River, based on observed harvest in the gill-net fishery (J. Polos, USFWS, pers. commun.). Some specimens have been observed in the estuary within six miles (9.7 km) of the river mouth; large white sturgeon (350-500 lbs; 159-227 kg) have been found as far upstream as RM 34-36 (Adair et al. 1983; Tuss 1989a). Whether white sturgeon reproduce in the Klamath River is unknown (Tuss 1989a), but there is no evidence that white sturgeon found there originate from other river systems (Adair et al. 1983, 1985).

There are few reports of white sturgeon in the upper Klamath River Basin. The ODFW planted about 200 fish in the upper basin during the late 1940s. These 200 sturgeon were originally rescued from the Bonneville Dam draft tubes (Donaldson 1958, unpublished manuscript). One fish was found in Lost River a year later. In 1975, a 69-pound (31 kg), 66-in (168 cm) sturgeon was caught and photographed at the mouth of the Williamson River, a tributary to Klamath Lake (letter and news clipping in ODFW files).

Klamath/Trinity River Basin white sturgeon populations are minor or possibly declining, based on miscellaneous harvest data (see Section V.G.).

Oregon Coast

Sport harvest data for 1986-1990 indicate white sturgeon use the Nehalem River and Bay, Tillamook Basin, Nestucca River and Bay, Siletz River and Bay, Yaquina River and Bay, Alsea River and Bay, Siuslaw River and Bay, Umpqua Basin, Coos River Basin, Coquille River Basin, Rogue River and Bay, and Chetco River and Bay (ODFW, unpublished data). Descriptions of the relative abundance of white sturgeon along the Oregon coast are not available. Since reproduction is not reported in any of these river basins, at least some sturgeon must travel through marine waters near the Oregon coast. This can also be confirmed by the capture of tagged white sturgeon from the Sacramento-San Joaquin River Estuary and Columbia River in some of the coastal Oregon and Washington waters.

White sturgeon are occasionally taken incidental to ocean groundfish trawl fishing activities along the Oregon coast. Occasionally trawl fishermen will target a known sturgeon abundance off the mouth of the Columbia River.

Rogue River (Oregon)

The Rogue River drains the southwestern corner of Oregon. Lost Creek Dam regulates the river flows, although this effect is moderated by accretion flows from unimpounded tributary streams. The land use of the river basin is unique; much of the lower river flows through wilderness. The Rogue River Estuary is short, shallow (mean depth <10 ft; <3 m) and narrow, but drains a large river basin (Everest 1973; Percy et al. 1974). Saline water intrudes about 2.5 miles (4 km) upstream, and the tide influences the river for about four miles (6.4 km) upstream (Everest 1973).

White sturgeon were found in the Rogue River upstream to Savage Rapids Dam at RM 107 and in the Illinois River to Illinois Falls at RM 39 (Rivers 1964). Today most of the directed sturgeon fishery occurs in large deep pools found in the "canyon," RM 24.9-68.4. The canyon has a gradient of 12.6 ft/mi (2.4 m/km); the lower river (RM 0-24.9) has a gradient of 3.7 ft/mi (0.7 m/km; ODFW 1989).

The Rogue River Basin may support a reproducing population of white sturgeon (T. Satterthwaite, ODFW, pers. commun.; A. Smith, ODFW, pers. commun.). The ODFW has conducted a 20-year beach seining project that incidentally caught both green and white sturgeon of various sizes. These data are under agency review.

Coos Bay (Oregon)

Coos Bay is the largest estuary along the Oregon coast south of the Columbia River (Percy et al. 1974). About 30 tributaries enter the estuary, which extends 12 miles (19.3 km) from the ocean to the confluence of the South Fork Coos River and the Millicoma River (Percy et al. 1974). The tide influences the South Fork Coos River and the Millicoma River upstream about nine miles (14.5 km). The mean tidal range is 5.2 ft (1.6 m) and tidal currents have a mean range of 3.4-5.9 ft/s (1.0-1.8 m/s; Percy et al. 1974).

Although sturgeon fisheries in Coos Bay have never produced large catches, there is evidence that sturgeon have had a long presence in the bay. A Fish Commission of Oregon report (Cleaver 1951) lists annual commercial catches of green sturgeon in Coos Bay from 1923-1949. The catch averaged 638 lb per year, with a range of 67 lb (1941) to 1,957 lb (1946). No landings of white sturgeon were reported. A limited, but persistent, sport fishery has existed in the bay for many years without catch enumeration. With the inception of the Oregon sport sturgeon tag in 1986, a means of estimating sport catch by species and river now exists. Catch records on returned tags from 1986-1990 indicate Coos Bay sport catch averages about 80 white and five green sturgeon per year.

Umpqua River (Oregon)

The Umpqua River Basin drains a large (4,560 sq mi; 1,181,040 ha) watershed and has the third largest estuary (south of the Columbia River) along the Oregon coast (Percy et al. 1974). Three major tributaries enter the estuary. The Umpqua River is relatively low gradient and the tide influences the river for about 27 miles (43.4 km) upstream from the estuary. The mean tidal range is about 5 ft (1.5 m; Percy et al. 1974).

Although white sturgeon are found in the Umpqua River, there is no evidence of reproduction in this basin (Johnson 1988). The fish probably come from other basins; at least a few individuals collected in the Umpqua River had been tagged in the Sacramento-San Joaquin River Estuary (Kohlhorst et al. 1991) and Columbia River.

Data describing the abundance or population status of Umpqua River sturgeon are not available. However, the rapid growth of white sturgeon in the Umpqua River and a declining catch rate prompted the ODFW in 1989 to transport sturgeon (most fish 24-36 in TL) from the Columbia River to the Umpqua River (Johnson 1988, 1989). Only 33 of 540 sturgeon netted in the Columbia River survived to be released in the Umpqua River.

Yaquina River (Oregon)

The Yaquina River and its major tributary, Elk Creek, drain into Yaquina Bay. The currents of the estuary are variable and tidal influence extends up to the community of Newport. The lower estuary is maintained as a deepwater port.

The 1988 draft of the ODFW Yaquina Basin Management Plan states that white and green sturgeon use Yaquina Bay. The white sturgeon may be migrants from the Columbia River, based on the Columbia River recovery of a fish tagged in Yaquina Bay (H. Horton, OSU, pers. commun.), and/or from the Sacramento-San Joaquin Estuary, based on a Yaquina Bay recovery of tagged fish from that system (Kohlhorst et al. 1991). Sturgeon move into Yaquina Bay during the late winter and early spring, remaining there from April to mid-July. At least some individuals move up the Yaquina River 11 miles (17.7 km), residing in deep holes at Riverbend (RM 5) and Mill Creek (RM 11). Movement of sturgeon may be associated with tides. As the temperatures warm in the summer, the fish move into the bay or the ocean (ODFW, unpublished draft).

Approximately 100-140 legal-sized (36-72 in; 91-183 cm) white sturgeon used Yaquina Bay annually from 1980 to 1985 (Draft Yaquina Basin Management Plan 1988). Although no larvae or eggs were found, the article notes observations of white sturgeon <24 in (<61 cm), but minimum size was not reported.

Tillamook Bay (Oregon)

Tillamook Bay is the second largest bay along the Oregon coast (Percy et al. 1974). The bay is about 6 miles (9.7 km) long and 3 miles (4.8 km) wide (ODFW 1974). The Kilchis, Miami, Tillamook, Wilson, and Trask rivers enter the bay. The mean tidal range is 5.7 ft (1.7 m; Percy et al. 1974). The salt and fresh water in the estuary are generally present as two layers, however there are reports of the salt and fresh water being "well mixed" in April and October (Percy et al. 1974; OSU 1976). The upper portion of the estuary usually contains fresh water.

A long-standing sturgeon fishery has been present in Tillamook Bay. The fishery effort and catch escalated in 1980 after the eruption of Mount St. Helens caused dispersal of sturgeon from the Columbia River into the ocean. Since 1980, the fishery level has remained relatively high, especially in the late winter and spring. Anglers have reported tags from the Sacramento and Columbia rivers in recent years. Very small sport fisheries occur in Nehalem Bay, five miles north of Tillamook Bay, and Nestucca Bay to the south.

Washington Coast-Puget Sound

Along Washington's coast, white sturgeon are caught in bays, estuaries, and in nearshore areas of the Pacific coast. These sturgeon probably migrate from the Columbia, Fraser, or Sacramento-San Joaquin River systems into these coastal areas. White sturgeon use Grays Harbor and Willapa Bay along the Washington coast (Boomer and Joner 1989). Concentrations of sturgeon occur south and east of Cape Flattery near Spike Rock off ShiShi Beach and in Muckhaw on the Washington coast (Boomer and Joner 1989). White sturgeon also use the Straits of Juan De Fuca and Puget Sound. The white sturgeon in Puget Sound may originate from the Columbia River Basin since tagged Columbia River fish have been recovered in Puget Sound (J. DeVore, WDF, pers. commun.).

There were no estimates of white sturgeon abundance for any Washington bay, river, coastal region, or Puget Sound. Harvest data provide an idea of abundance. In 1988, sportsmen harvested about 1,960 white sturgeon in Willapa Bay and Grays Harbor while commercial fishermen landed 1,450 white sturgeon (Zinicola and Hoines 1988). Ocean commercial landings (in Washington) averaged 600 fish, but varied from 100-2,700 fish between 1971 and 1989 (WDF, unpublished data).

Canadian and Alaskan Coastal Waters

White sturgeon probably do not reproduce in Alaska, but there are several old reports of white sturgeon in Alaska. Donaldson (1958, unpublished manuscript) reported a sturgeon in Naknek Lake, Alaska. Scott and Crossman (1973) reported sturgeon throughout the coastal regions of Alaska. A white sturgeon was caught in Cook Inlet (D. Lane, Malespina College, pers. commun.). One Columbia River white sturgeon tag was recently returned from the Naknek River in Alaska, but the credibility of this report is suspect (J. DeVore, WDF, pers. commun.). Data were not available for Canadian coastal areas.

III. ECONOMIC VALUE

A. COMMERCIAL VALUE

White sturgeon provide fresh or processed fish flesh, caviar, and fingerlings for export or U.S. sale, and viable gametes for culture. It is possible to estimate the value of the flesh sold, but not other commodities. The value of white sturgeon flesh on the Pacific Coast, based on ex-vessel prices, was a minimum of $0.6 million to $3 million annually between 1978 and 1988. Using an economic multiplier of 3.7 (Washington Department of Commerce and Development 1988) to estimate the impact of these sales on the communities, the commercial harvest of white sturgeon was worth between $2.2 million and $11.1 million annually from 1978-1988.

Fish Flesh

Each year the demand for seafood increases. In the United States, the per capita consumption of seafood increased 25% between 1982 and 1987 (Natural Resource Consultants 1988). U.S. exports to Japan dramatically increased between 1985 and 1988 with the devaluation of the yen. Recent declines of Atlantic Ocean yields of white fish flesh, the largest portion of the seafood market, increased demand for Pacific Coast seafood.

The price of sturgeon caught by commercial fishermen reflects the growing demand for seafood. From 1978-1989, the price of white sturgeon flesh tripled. In 1989 the average ex-vessel price of sturgeon caught by commercial fishermen was slightly less than $2/lb ($4.40/kg).

The rapid growth of white sturgeon and relatively high economic value of the flesh prompted development of the commercial aquaculture industry during the 1980s (see Section VI). A market has been developed for fresh fish between 5 lb and 40 lb (2.3-18 kg). Commercial facilities can produce 5-30 lb fish within 2-4 years. Two-year-old fish are about 5-7 lb (2.3-3.2 kg); 3-year-old fish, 12-14 lb (5.5-6.4 kg); and 4-year-old fish, 20-30 lb (9.1-13.6 kg). Estimates of the volume of sturgeon flesh sold by commercial aquaculture facilities and the estimated value of the industry are unavailable.

Caviar

There is both a U.S. and international market for processed sturgeon roe. The former Soviet Union provides most of the world's caviar from its endemic sturgeon species. Iran and Canada also produce caviar for export. The United States imports caviar from Canada and the former Soviet Union, but trade sanctions do not permit importation of Iranian caviar. White sturgeon caviar from the Columbia River (when available) retails locally for $8-10/oz ($0.28-0.35/g).

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White sturgeon roe is only occasionally available from the commercial fishery due to the maximum length limit. At present, the aquaculture industry does not produce caviar or sell roe. The price paid by fish buyers for white sturgeon roe depends both on egg quality and whether the fisherman knows the catch contains roe (D. Swartz, ODFW, pers. commun.). If the fisherman confirms a legal fish has roe, the roe is sold separately. High quality roe consists of shiny black eggs with little or no fat tissue and yields about 40% caviar by weight (D. Swartz, ODFW, pers. commun.). Lower grades of roe consist of gray eggs and fat tissue, requiring more effort to process. When the eggs are of poor quality, they are processed before pricing. If the fisherman is unaware that a fish has roe, the whole fish is sold at the flesh price and roe is not recorded by the buyer.

Sturgeon roe was worth $7.53/lb ($16.59/kg) between 1988 and 1989 wholesale, or about four times the value of white sturgeon flesh in the round (preliminary data from NMFS Fishery Market News, March 7, 1990). Oregon buyers quoted 1990 wholesale roe prices at $8-24/lb ($17.62-52.86/kg; D. Swartz, ODFW, pers. commun.).

The value of caviar and unprocessed roe induces illegal marketing of oversized fish (Galbreath 1985; D. Kohlhorst, CDFG, pers. commun.). For instance, one enforcement officer reported about 30-35 oversized white sturgeon taken illegally from Bonneville Pool in 1986 (ODFW interoffice memorandum from King, dated January 26, 1987). In California, there is evidence of illegal sale of gravid females by a few poachers who spend much of the late winter and spring camped along the Sacramento River (D. Kohlhorst, CDFG, pers. commun.).

Records of the annual purchase of roe are not complete. The WDF estimates that from 1985-1989 about 670 lb of usable roe from Columbia River commercial fisheries were processed annually (J. DeVore, WDF, pers. commun.).

<u>Live Fingerlings and Subadult Fish</u>

Commercial incubation facilities sell sturgeon fingerlings to grow-out facilities in California, Washington, other non-Pacific states, and foreign countries. Italy, France, Israel, China, and Japan import white sturgeon fingerlings. Commercial culture facilities in Wisconsin, Michigan, Missouri, and South Carolina may also rear white sturgeon (Marx 1986).

The White Sturgeon Planning Committee was not able to determine the value of the fingerling market. The costs of gamete collection, incubation, and rearing to fingerling market size are not available. Botsford and Hobbs (1984) estimated that it costs between $0.15 and $1 to raise a 1-in (3 cm) sturgeon to 14 in (35 cm). According to Beer (1989), fingerlings (4 in; 10 cm) sell for about $1, and 36-in (91 cm) fish sell for $30. Another grower indicated that fingerlings sell to the aquarium market for about $0.50-1/in ($0.20-

0.39/cm; anonymous commercial grower, pers. commun.). Total sale volume and estimated industry value are unavailable.

Viable Gametes

Private culturists use primarily domestic males and wild females for viable gametes, although Columbia River culturists operating under Oregon permits use wild males and females collected in the lower Columbia River. The two Oregon culturists are limited to a combined total collection of 12 females (may be >6 ft) and 24 males (<6 ft) from the lower river from April through June. The cost of gametes includes the cost of broodstock collection, annual collection permits, and maintenance costs for domestic broodstock. Estimates of broodstock collection costs were unavailable except for collection permits that cost $10 in Oregon and $25 in California annually. California aquaculturalists spawned a few domestically reared females in 1990 and hope to have sufficient hatchery-reared broodstock of both sexes for their needs in the near future.

B. RECREATIONAL VALUE

Anglers seek sturgeon for their size, sporting qualities, and excellent flesh. The species is also available to the angler for most of the year. Whether or not they can retain the sturgeon they catch, anglers continue to fish for sturgeon throughout the Pacific states.

There are various methods commonly used to determine the value of recreational fisheries, including expenditures related to fishing (such as the travel cost method), willingness to pay, and total economic value (including economic impact on the state or region; Duffield et al. 1987). Botsford and Hobbs (1984) offered an economic value estimate of white sturgeon recreational fisheries. The value was based on the weight of the fish, although the value may not be directly proportional to weight. They estimated a sturgeon to be worth $0.45-1.36/lb ($1-3/kg) in the sport fishery, which is less than current ex-vessel values. Since there are few economic assessments of sturgeon angler days, the following analyses use approximations from the literature.

Using the published IDFG value of a warmwater fishing trip in western Idaho of $42/day and an estimated 210,859 angler-days directed at sturgeon in 1988 (A. VanVooren, IDFG, pers. commun.), the value of the recreational sturgeon fishery in Idaho in 1988 was about $8.9 million.

The value of the recreational sturgeon fishery (all species combined) in the Sacramento-San Joaquin River system was about $1.9 million to $3.1 million in 1990, based on $47.08/angler day and an estimated 40,000-65,000 angler days (D. Kohlhorst, CDFG, pers. commun.). The value of the sturgeon fishery rises to about $5.5 million to $9 million in 1990, if the net income (for the community) per person per angler day ($90.83) is included. Estimates are based on 1983 values from Meyers Resources, Inc. (1985) expanded 4% per year to 1990 values.

Using a value of a striped bass fishing trip in the Sacramento River of $25-40/day and applying it to the estimated 135,000-175,000 angler days annually for the lower Columbia River (below Bonneville Dam) in the 1980s, the sturgeon fishery was valued at about $3.4 million to $7 million annually (D. Swartz, ODFW, pers. commun.). No estimates of total angler days are available for the sport fishery in Oregon and Washington above Bonneville Dam.

The value of the sturgeon fishery along the Oregon coast is $0.3 million to $0.6 million annually, using $25-40/day as the value of an angler day (see previous paragraph) and an estimated 11,700-13,100 angler days per year. This value was estimated from a catch of 2,100 annually (1986-1989) and an estimate of 0.16-0.18 fish/angler for the same period (ODFW, unpublished data).

The value of the sport fishery along the Washington coast could not be quantified. No estimates of total angler days or the value of an angler day were available for the Fraser River sport fishery.

The minimum estimated annual value of the white sturgeon sport fishery (based on value per angler day) in the Pacific states was $14.5 million to $19.6 million. The net value of the sturgeon sport fishery to the communities serving the sturgeon angler may be an additional $36.1 million to $42.1 million annually, based on California's estimated $90.83/angler day. Hence, white sturgeon provide the Pacific states about a minimum $50.6-million to $61.7-million economic return annually.

C. CEREMONIAL AND SUBSISTENCE VALUES

Sturgeon are taken as part of the Native American subsistence fishery. However, as there are no data quantifying catch (see Section V), it is not possible to estimate the magnitude and value of the subsistence fishery. There is no ceremonial use of sturgeon by Native Americans.

IV. FISHERY MANAGEMENT JURISDICTION, LAWS, AND POLICIES

A. MULTI-JURISDICTIONAL NATURE OF STURGEON MANAGEMENT

The Pacific States Marine Fisheries Commission is an interstate compact agency established in 1947. The purpose of the PSMFC is to represent the interests and needs of Pacific Coast marine fisheries and the regulatory agencies from each member state. Member states are Alaska, Washington, Oregon, California, and Idaho. The goal of the commission is "to promote and support policies and actions directed at the conservation, development, and management of fishery resources of mutual concern to member states through a coordinated regional approach to research, monitoring and utilization." The PSMFC provides a forum for representing issues and resolving fisheries management conflicts. The commission works toward coastalwide consensus opinion for sensitive issues and then carries the Pacific Coast position to appropriate state and federal forums.

The PSMFC does not have direct management authority for fisheries resources. Each state manages non-treaty sturgeon harvest and fishing opportunity within its coastal and inland waters. Each tribe is a sovereign government and regulates its own fisheries in consultation with state and federal co-managers. States may impose regulations on tribes only if the state can demonstrate tribal regulations would imperil the resource. Federal agencies provide habitat management and biological monitoring assistance to the tribes and regulate the import and export of commercial fish products.

<u>Management of the Sacramento-San Joaquin, Columbia, and Fraser Rivers</u>

The California Fish and Game Commission sets regulations for recreational angling in the state, based on recommendations from the California Department of Fish and Game. The U.S. Fish and Wildlife Service (USFWS) monitors the tribal interception of sturgeon (in the salmon fishery) in the Klamath River within the Yurok Indian Reservation, but does not have the authority to alter regulations influencing sturgeon harvest.

The non-treaty and treaty commercial and treaty subsistence fisheries of the Columbia River below McNary Dam are regulated by the Columbia River Compact. The compact was ratified by the U.S. Congress in 1918. Recommendations for the non-treaty commercial fishery below Bonneville Dam are developed and presented to the compact by the joint Oregon/Washington Columbia River management staff. Recommendations for the treaty fisheries are the province of the Sturgeon Management Task Force (SMTF). The SMTF is an informal committee, formed in 1988, whose members are the ODFW, WDF, Yakima Indian Nation (YIN), Nez Perce Tribe, Warm Springs Tribe, and Umatilla Tribe.

Responsibility for the recreational fishery management from the mouth of the Columbia to McNary Dam lies with the states of Oregon and Washington, which border the river. Upstream from McNary Dam, Oregon, Washington, Montana, and Idaho manage the fisheries resources in their respective sections of river. There is no formal interstate process to develop recreational regulations for this region. Washington and Oregon are committed to enacting consistent regulations in jointly managed Columbia River waters.

International management of Kootenai River sturgeon is an informal process. To date, there are no legal agreements providing standard policies, goals, or recreational regulations for sturgeon management in the British Columbia, Idaho, and Montana reaches of the river. Managers and research scientists from British Columbia and Idaho meet regularly to discuss sturgeon research and management in the Kootenai River Basin.

In British Columbia, two agencies manage white sturgeon, the Canadian Department of Fisheries and Oceans and the British Columbia Ministry of Environment and Parks (BCMEP). The Department of Fisheries and Oceans manages commercial fisheries, managing sturgeon downstream from the Mission Bridge in the Fraser River. The BCMEP manages the sport fishery upstream from the Mission Bridge in the Fraser River Basin. There are four districts of the BCMEP that set regulations independently. The ministry expects to establish consistent sport regulations throughout the province.

Other Coastal Estuaries and Marine Management

Sturgeon management in the smaller coastal rivers, estuaries, and nearshore ocean areas does not usually consider the river, state, or country of fish origin. Sturgeon collected along the coast and in smaller estuaries generally represent mixed stocks. Although individual sturgeon may migrate between states or into Canada, there are no formal management or research exchange agreements. Informal communications on an individual basis provide limited information exchange about white sturgeon throughout the Pacific states.

The California Department of Fish and Game (CDFG), the ODFW, and the WDF manage sturgeon along the California, Oregon, and Washington coasts, respectively. There are no interstate agreements to coordinate the coastal sturgeon harvest. In Washington, the Northwest Indian tribes cooperatively manage the treaty and non-treaty commercial fisheries that catch white sturgeon in ocean and estuarine areas along the Washington coast. Sturgeon caught on sport gear in the ocean or in estuaries are under the jurisdiction of the state of the angler's port.

B. STATE LAWS, REGULATIONS, AND POLICIES

Each state establishes regulations for sport fisheries and commercial acti· its boundaries. These regulations combine social needs, management of other ; sturgeon biology. Regulations require moderately priced licenses or permits foı ... commercial uses. In some states, the right to fish includes data collection and reporting responsibilities.

Sale of sturgeon caught with commercial gear (gill net or in the tribal setline fishery), is legal in Washington and Oregon only. Details of these regulations are found in Section V of this document.

Commercial sturgeon aquaculture policies are under consideration or in force throughout the Pacific states. Sturgeon aquaculture policies regulate the collection of gametes, size of fish reared, planting of "replacement fish," broodstock origin requirements, and controlling diseases of imported fish. Oregon, Washington, and Idaho prohibit the import of white sturgeon eggs or fish from the Sacramento-San Joaquin River Basin. Idaho also prohibits the introduction of sturgeon eggs or fish from outside the state. California and British Columbia permit import of fish and eggs from other regions. Export of live sturgeon, eggs, or other sturgeon products is legal throughout the Pacific states, under various regulatory requirements. For instance, Oregon prohibits export of live sturgeon over 6 in (15 cm) TL.

Resource agencies in the region generally use existing agency culture and fish transport policies for white sturgeon. Transporting wild or hatchery sturgeon between basins is no longer acceptable in most states due to disease and genetic concerns. Management efforts minimized the spread of the white sturgeon virus, which was observed for the first time in California culture facilities in 1988.

C. TRIBAL LAWS, REGULATIONS, AND POLICIES

Native American tribes are independent governments that set their own fishing regulations, but also participate in a co-management process with state and federal agencies. In California, the Yurok Tribe, through the auspices of the Bureau of Indian Affairs' Indian Trust responsibility, coordinates with the U.S. Fish and Wildlife Service Coastal California Fishery Resource Office. Along the coast of Washington and the Columbia River, there are two advisory groups that facilitate tribal coordination with state agencies -- the Columbia River Inter-tribal Fish Commission (CRITFC) and the Northwest Indian Fisheries Commission. Tribal fishers generally are not interested in catch-and-release fishing; this concept is counter to the Indian ethic of resource use, which emphasizes personal subsistence.

In the Columbia River Basin, the tribes present their commercial and subsistence fishing regulation recommendations for the areas fished to the coordinating agencies. Along the Columbia River, the tribes coordinate their annual regulations through the CRITFC and the Sturgeon Management Task Force. The tribes then present their recommendations through the CRITFC or SMTF to the Compact. The Columbia River Compact usually adopts the proposed regulations. The tribes and the states then issue their own, but consistent, regulations for white sturgeon.

Descriptions of the tribal regulation process were unavailable for other areas.

V. EXPLOITATION BY MANAGEMENT UNIT

The history of white sturgeon exploitation in the major river basins of the Pacific states shares a common course. The development of the canning industry in 1866 initiated the commercial salmon fishing industry. Sturgeon were incidentally harvested in salmon gear and destroyed as nuisance or unwanted fish. As salmon runs declined, the acceptance of other fish species in the market place increased. In the late 1880s and early 1890s, the commercial value of fresh and smoked sturgeon increased. The sturgeon industry expanded dramatically as freezers became available and caviar became a popular and valuable item in the market place. The sturgeon populations in the Sacramento-San Joaquin, Columbia, and Fraser River basins collapsed after only 5-10 years of unregulated, targeted commercial exploitation. Management responded with fish size, season, and sometimes bag regulations in each major river basin. Early attempts at aquaculture failed. Commercial harvest continued, primarily as incidental net catch associated with salmon fisheries. By 1910, sturgeon provided a minor fishery throughout the region.

Biologists became interested in white sturgeon biology with the construction of hydropower and irrigation reservoirs in the 1950s and 1960s. Water quality had declined with the growth of population and centers of industry in the western United States. Exploitation, harvest allocation, restricted river passage, and habitat degradation reduced the number of salmon available to sportsmen. Sport fishing interest in white sturgeon increased at a rapid rate throughout the Pacific states in the 1970s. Aquaculture techniques for the propagation of white sturgeon developed for commercial purposes during the 1980s.

A. SACRAMENTO AND SAN JOAQUIN RIVERS

History of Fishing

Schulz and Simons (1972) documented the prehistoric Native American use of white sturgeon in the Sacramento-San Joaquin River Delta near Stone Lake at the north end of the delta.

Exploitation of white sturgeon in the late 1880s resulted in the collapse of the fishery by the late 19th century (Chadwick 1959; Skinner 1962). San Francisco Bay was the center of commercial sturgeon harvest (McDonald 1894). Most commercial sturgeon were caught on setlines or "China" gang-lines in San Francisco Bay and the lower reaches of the Sacramento and San Joaquin rivers (McDonald 1894). Setlines caught sturgeon of all sizes. Unlike other parts of the region, there was a ready market in San Francisco for the small (15-18 in; 38-46 cm) fish (McDonald 1894). Fishermen sought large female sturgeon with roe; the roe was often as much as 20% of their body weights. Marketable meat was about 54% of their total body weights (McDonald 1894).

After the fishery was intermittently opened and closed, legislation prohibited all sturgeon fishing in 1917; commercial sturgeon fishing never resumed in the Sacramento-San Joaquin River system (Skinner 1962). During the targeted fishery and after the close of commercial sturgeon fishing in 1917, there was an incidental sturgeon harvest associated with gill-net fisheries for salmon and shad (Skinner 1962; Miller 1972b). Any commercial gear that would incidentally catch sturgeon was legislatively prohibited in the Sacramento-San Joaquin River Basin in 1957 (Skinner 1962).

In 1954, a sport fishing season opened for white sturgeon with a 40-in (102 cm) TL minimum size limit and a 1 fish/day creel limit (Botsford and Hobbs 1984; Kohlhorst et al. 1991). Snagging was a legal form of sport fishing until 1956 (Miller 1972b). White sturgeon also were caught incidentally by striped bass anglers. In 1964, shrimp became a popular bait, increasing sturgeon vulnerability and sport harvest (Miller 1972b).

Distribution of the catch by fishing method in the Sacramento-San Joaquin Estuary in 1967 and 1968 was described by Miller (1972b). Seventy-four percent of the white sturgeon catch was taken on private boats, about 20% on charter boats, and 5% from shore. More recently, anglers on private boats have accounted for 84% of the white sturgeon catch; charter boats, 10%; and shore anglers, 6% (D. Kohlhorst, CDFG, pers. commun.)

Kohlhorst (1980) used logs from charter boats to estimate angler success rates (CPUE) and to evaluate population trends. Fish size in the catch increased while the population declined between 1967 and 1974. This pattern suggested the decline was due to a lack of recruitment to harvestable size.

There was a rapid expansion of the white sturgeon recreational fishery in the Sacramento-San Joaquin Estuary in the 1970s. This interest in white sturgeon accompanied the decline of the popular striped bass fishery.

Exploitation rate increased about 40% during the 1980s (Kohlhorst et al. 1991). The increased harvest was the result of both increased angler effort and efficiency. Population modeling showed that annual exploitation rates, which were greater than 10% in the mid- to late 1980s, would lead to a substantial population decline. The CDFG recommended reduced harvest to the Fish and Game Commission in 1989 and presented regulation changes that would accomplish this over a four-year period. The commission adopted recommended regulations increasing the minimum size limit to 42 in (107 cm) TL in 1990 and 44 in (112 cm) TL in 1991. For the first time in California, a maximum size limit of 72 in (183 cm) was also instituted. The CDFG plans to propose additional increases in the minimum harvestable size limit of 46 in (117 cm) TL in 1992, and 48 in (122 cm) TL in 1993 to attain Management Goal 1 (see below). The maximum harvestable size will remain 72 in (183 cm).

In 1990, sturgeon anglers could fish all year throughout California, except for seasonal closures in central San Francisco Bay to protect a concentration of sturgeon feeding on herring eggs and in the Klamath River (see Section V.G.). Anglers may currently keep one fish between 44 in and 72 in (112-183 cm) per day. Fish must be landed without the use of a gaff.

There are no ceremonial or subsistence fisheries by Native Americans for white sturgeon in the Sacramento-San Joaquin River system.

Current Harvest Management Goals

Current management goals for the Sacramento-San Joaquin Estuary white sturgeon population are to:

1) Reduce harvest observed in the 1980s by approximately 50% by March 1993.

2) Protect large, fecund females from harvest.

3) Maximize recreational fishing opportunity for white sturgeon consistent with maintaining the population.

4) Maintain equal access to the resource for all sport anglers.

The state will continue to issue permits for wild broodstock collection if the operator is attempting to develop captive broodstock. The goal is to phase out collection of wild broodstock as domestic broodstock becomes available.

B. COLUMBIA RIVER DOWNSTREAM FROM BONNEVILLE DAM

History of Fishing

Native Americans harvested white sturgeon in the Columbia River region; some fish were sold to white explorers (Craig and Hacker 1940). Data identifying traditional Native American sturgeon fishing sites or ceremonial use of sturgeon in the Columbia River are unavailable.

Salmon fishermen using gill nets, traps, and fish wheels in the 1870-1890s considered sturgeon a safety hazard and nuisance. Large and small specimens alike were carelessly handled or killed.

The first record of a white sturgeon sale was in 1884. By 1888, a commercial white sturgeon fishery had begun. At first, fish were sold fresh. Soon freezing, salting, smoking, and canning made it possible to ship sturgeon to San Francisco and East Coast markets. About 94 tons (85 t) of preserved sturgeon were shipped out of the region in 1888.

The first sturgeon fishing camp was at Oneonta, Oregon, located 12 miles (19.3 km) downstream from present day Cascade Locks and 33 miles (53.1 km) upstream from Portland (by rail; Craig and Hacker 1940). Sturgeon flesh was frozen for shipment from this camp for the first time in 1889. Between January and May 1889, about 85 tons (77 t) were shipped to the East Coast from Oneonta. There was a demand for sturgeon flesh in the winter, while summer markets in the East sought roe. The sturgeon fishery lasted from August to April. This time period did not interfere with the salmon fishery and gave fishermen a chance to work during the winter.

The average-sized sturgeon in the commercial catch was 150 lb (68 kg), but 500-pound (227 kg) fish were common. Fish over 800 lb (363 kg) were taken at Oak Point (RM 53) and near the mouth of the Kalama River (RM 73).

In 1888, the first year of commercial harvest, about 1 million lb (454 t) of fresh or pickled white sturgeon were sold with a value of $15,000 ($.015/lb). The peak harvest year was in 1892 when 5.5 million lb (2,494 t) of flesh and secondary products (roe, spinal marrow, and isinglass) sold for $41,000. Fish were taken with Chinese gang lines and large mesh gill nets. Chinese gang lines were strings of lines on the river bottom with unbaited hooks intended to snag sturgeon.

The fishery in the lower Columbia River collapsed by 1894, causing fishermen to travel upstream in search of large fish. By 1893, the average size of sturgeon harvested in the Columbia River had dropped from 150 lb (68 kg) to 50 lb (23 kg) per fish. Fish under 50 lb (23 kg) were considered too small to be worth harvesting.

Commercial harvest was not the only source of mortality for sturgeon. Fish wheels caught hundreds of sturgeon less than 50 lb (23 kg) daily. Small fish caught in fish wheels, gill nets, and traps were often destroyed, for they were considered a nuisance to the salmon industry.

The sturgeon fishery in the remaining river reaches had collapsed by 1899. Harvest regulations included a 48-in (122 cm) TL minimum size limit and a shorter, six-month season. Regulations did not change again for 50 years (Appendix Table C2a). Harvest during this period was modest. By the 1940s, commercial sturgeon harvest was primarily an incidental catch in salmon gill nets with some directed catch from baited setlines. Small quantities of sturgeon flesh were smoked and canned in oil.

Research in the late 1940s prompted regulation changes. The 1950 regulations included a maximum size limit of 72 in (183 cm) TL; this change was based on Bajkov's Columbia River sturgeon research. Sport regulations were refined during the next 10 years (Appendix Table C2b). White sturgeon harvest levels from 1950-1970 remained small and were primarily incidental commercial harvests (Galbreath 1985). The recreational fishery was at a low level and directed at salmon and steelhead until these populations declined in 1974. By 1976, the sturgeon sport fishery was increasing due to closed salmon and steelhead seasons. Table 4 and Figure 13 show Columbia River white sturgeon commercial landings 1889-1959.

Recent Commercial Harvest

With declining commercial salmon opportunity due to depressed upriver salmon runs, beginning about 1974, managers and industry began to develop target sturgeon fisheries to somewhat offset economic hardship. The sturgeon population had recovered since the protection of broodstock fish in 1950. The population of 4-6 ft (1.2-1.8 m) legal-sized fish was large and the sport fishery was at a relatively low level.

A separate season for commercial sturgeon harvest using setlines was established in 1975. Setline fisheries lasted 1-9 months from 1975-1982. In 1982, the Washington Legislature passed a law requiring the phase-out of commercial setline sturgeon fishing below Bonneville Dam. The fishery was phased out from 1983-1985. Oregon cooperated in the phase out to avoid non-concurrent commercial fishing regulations.

To replace the pending loss of commercial setline opportunity, managers and industry tested the use of large mesh ($\geq$ 9 in; 23 cm) gill nets for sturgeon fishing. Managers found the nets to be effective on 4-6 ft (1.2-1.8 m) sturgeon. The nets also reduced the handling of sublegal sturgeon and salmon. Target large-mesh gill-net sturgeon fisheries (seasons of 1-3 weeks annually) began in 1983 and continued through 1988. During this same time, the recreational fishery rapidly expanded, especially in the estuary, due to restricted ocean salmon angling opportunity and the presence of a large abundance of 3-4 ft (0.9-1.2 m) sturgeon.

In 1988, managers began to define the combined sport and commercial exploitation rate for sturgeon below Bonneville Dam. They found it to be about twice that believed to be sustainable. Consequently, harvest restrictions were enacted.

Target gill-net sturgeon fisheries were reduced in 1988 and eliminated in 1989. The Columbia River Compact warned industry in 1989 that time and zones during salmon gill-net seasons could also be closed if sturgeon landings exceeded salmon landings. To date, times and zones within salmon seasons have not been closed. However, a 9-in (23 cm) maximum mesh restriction was placed on the October 1990 and 1991 coho salmon fishery in the upper fishing area between the Sandy River and Bonneville Dam (Area 2S) to reduce target sturgeon fishing.

Commercial landings below Bonneville Dam (Zones 1-5) are now around 4,000-5,000 sturgeon per year compared to the 1980-1987 average and the 1970s average of 12,000 fish each year (Tables 5, 10; Figure 14). The average weight of commercially landed sturgeon since the 1970s has been 30-35 lb (14-16 kg).

Table 4. Columbia River commercial catch (in thousands of lb) of white sturgeon, 1889-1959 (Cleaver 1951; Fish Commission of Oregon and WDF 1971).

Year	Zones 1-5 (Below Bonneville)	Zone 6 (Above Bonneville Dam)	Total[1]
1889	--	--	1,746.7
1980	--	--	3,084.9
1891	--	--	3,562.0
1892	--	--	5,466.8
1893-94			no data
1895	--	--	4,704.5
1896-98			no data
1899	--	--	73.3
1900-03			no data
1904	--	--	137.7
1905-14			no data
1915	--	--	134.9
1916-22			no data
1923	--	--	182.9
1924			no data
1925	--	--	231.4
1926	--	--	209.1
1927	--	--	211.5
1928	--	--	147.5
1929	--	--	159.6
1930	--	--	129.4
1931	--	--	112.9
1932	--	--	71.4
1933	--	--	84.5
1934	--	--	79.1
1935	--	--	72.8
1936	--	--	131.3
1937	--	--	127.3
1938	28.5	39.1	67.6
1939	45.7	28.2	73.9

Table 4 (cont.). Columbia River commercial catch (in thousands of lb) of white sturgeon, 1889-1959 (Cleaver 1951; Fish Commission of Oregon and WDF 1971).

Year	Zones 1-5 (Below Bonneville)	Zone 6 (Above Bonneville Dam)	Total[1]
1940	54.2	29.7	83.9
1941	60.6	24.0	84.6
1942	58.5	36.7	95.2
1943	86.0	30.1	116.1
1944	178.5	58.5	237.0
1945	195.6	70.5	266.1
1946	211.9	99.6	311.5
1947	215.7	159.4	375.1
1948	388.1	187.3	575.4
1949	249.2	142.6	391.8
1950	266.8	58.5	325.3
1951	225.5	31.9	257.4
1952	233.4	37.4	270.8
1953	322.7	23.8	346.5
1954	293.5	17.6	311.1
1955	202.8	20.1	222.9
1956	227.6	16.3	243.9
1957	303.6	8.1	311.7
1958	240.4	16.4	256.8
1959	167.5	35.9	203.4

[1] Figures for 1889-1934 include small amounts of green sturgeon.

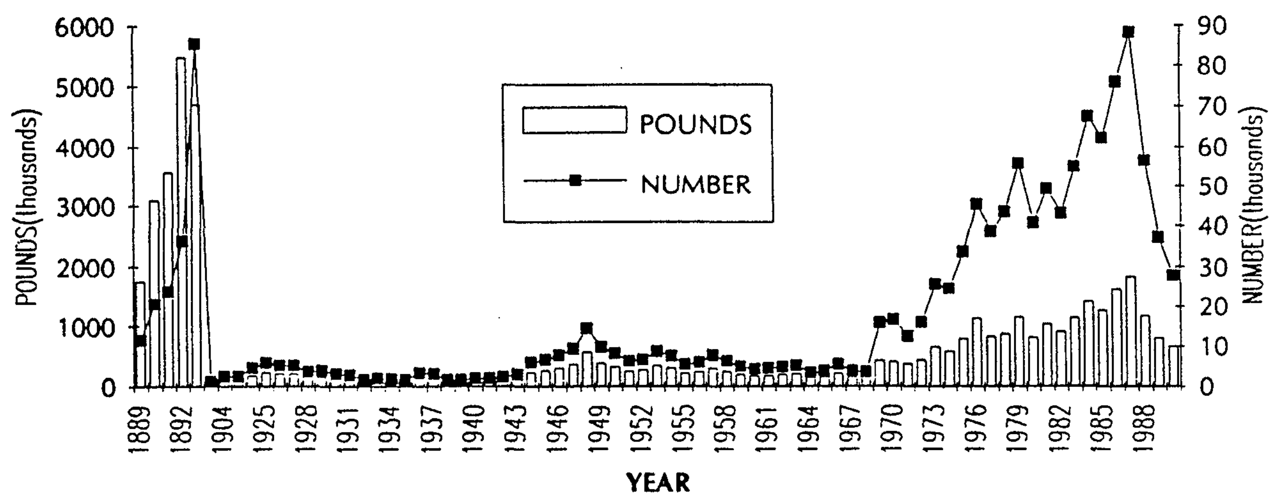

Figure 13. Columbia River commercial catch of white sturgeon, 1889-1990 (Cleaver 1951; Fish Commission of Oregon and WDF 1971; Melcher and King 1991).

Table 5. Columbia River catch (in thousands of fish) of white sturgeon, 1969-90 (ODFW and WDF 1991).

	Zones 1-5 (Below Bonneville Dam)			Zone 6 (Bonneville Dam - McNary Dam)			
	Commercial			Commercial			
Year	Gill Net[1]	Setline[2]	Sport	Setnet	Setline[3]	Sport	Total
1969	7.5	0.0	6.9	0.4	0.0	--	14.8
1970	6.3	0.0	8.9	0.4	0.0	--	15.6
1971	7.2	0.0	3.7	0.7	0.0	--	11.6
1972	7.6	0.0	6.6	0.7	0.0	--	14.9
1973	10.7	0.0	12.9	1.1	0.0	--	24.7
1974	10.7	0.0	12.3	0.5	0.0	--	23.5
1975	13.0	1.0	18.1	0.6	0.0	--	32.7
1976	18.1	4.7	19.3	0.4	0.2	--	42.7
1977	8.9	0.8	25.8	0.3	0.3	--	36.1
1978	8.8	1.0	30.4	0.4	0.3	--	40.9
1979	18.5	2.0	31.4	0.6	0.7	--	53.2
1980	6.8	2.6	27.0	0.4	1.4	5.0[4]	43.2
1981	10.8	4.1	27.2	0.3	1.8	5.0	49.2
1982	7.0	4.6	25.1	0.2	1.1	5.0	43.0
1983	9.5	2.9	36.0	0.3	1.1	5.0	54.8
1984	15.7	1.8	42.0	1.1	1.7	5.0	67.3
1985	7.6	0.8	43.8	3.0	2.0	5.0	62.2
1986	11.6	--	49.8	6.2	3.3	5.0	75.9
1987	9.7	--	62.4	7.9	3.2	5.0	88.2
1988	6.9	--	43.1	3.8	0.3	2.5	56.6
1989	5.0	--	25.4	3.1	0.4	3.4	37.3
1990	5.2	--	17.3	3.2	0.3	1.9	27.9

[1] Target sturgeon gill-net seasons eliminated in 1989.

[2] Prior to 1975, minor setline landings are included in gill-net totals. Setline fishing prohibited in Zones 1-5 in 1986.

[3] Minor setline landings during 1969-1975 are included in setnet totals.

[4] Based on limited sampling, sport catch estimated to average 5,000 fish annually from 1980-1986.

Recent Recreational Harvest

Sturgeon are popular sport fish for two reasons. Angler success is generally not dependent upon water conditions; only extremely cold water and extremely high flows or high winds decrease angler success (Reid and Mabbott 1987; Hess and King 1989). Secondly, catch rates for white sturgeon are generally good for the area. Catch rates per angler trip for lower Columbia anglers in 1990 were 0.13 legal fish kept, 1.76 sublegals released, and 0.01 oversized fish released (Melcher and King 1991).

Prior to 1970, the sport sturgeon catch in the lower Columbia River was relatively small and the fishery was centered in the Columbia River Gorge below Bonneville Dam. Beginning in 1974, lower Columbia sport salmonid fisheries were severely restricted to protect salmon and steelhead destined for areas above Bonneville Dam. At the same time, the sturgeon population below Bonneville Dam was quite healthy and increasing, primarily due to broodstock protective regulations enacted in the 1950s. With the lack of year-round salmonid angling opportunity and a large abundance of white sturgeon in the lower Columbia River, the angling community responded; sturgeon angler trips and catch doubled during the 1970s.

During the early 1980s, the lower Columbia River sport sturgeon fishery experienced further expansion, primarily in the estuary during the summer months. The driving force behind this expansion was shortened ocean salmon seasons. The estuary sport fleet, both private and charter, responded by turning its efforts toward the abundant white sturgeon. By 1987, the lower Columbia River sport sturgeon catch had peaked at a level twice that observed in the late 1970s. Beginning in 1989, Oregon and Washington instituted a three-year catch reduction regulation package designed to bring the combined sport and commercial exploitation rate down to about 15% annually. The results of this package are reflected in the precipitous decline in numbers of legal white sturgeon caught after 1988. Even with the reduced catch of legal-sized white sturgeon, it is interesting to note that totals for angler trips and sublegal and oversized fish released have remained high (Table 6). With the present large abundance of white sturgeon and development of a permanent interest by the angling community, it is believed sturgeon will remain one of the principal sport fish of the lower Columbia River.

White sturgeon angler effort on the lower Columbia River is year-round and takes place on much of the 145 miles of river below Bonneville Dam. The sport fishery can be divided into three different geographic areas -- Bonneville (RM 127-145), Troutdale-Westport (RM 38-127), and the estuary (RM 0-38; Melcher and King 1991). Each area has its own unique characteristics. Table 7 displays white sturgeon angler trips and catch for each of these sections for 1977-1990.

Table 6. Lower Columbia River white sturgeon sport angler trips, legal fish kept, and sublegal and oversized fish released by year, 1969-1990 (Melcher and King 1991).

Year	Angler trips[1]	Legals kept	Sublegals released[2]	Oversizes released[2]
1969	--	6,900	--	--
1970	--	8,900	--	--
1971	--	3,700	--	--
1972	--	6,600	--	--
1973	--	12,900	--	--
1974	42,400	12,300	--	--
1975	60,300	18,100	--	--
1976	56,800	19,300	--	--
1977	55,100	25,800	--	--
1978	82,500	30,400	--	--
1979	101,000	31,400	--	--
1980	105,900	27,000	--	--
1981	116,800	27,200	--	--
1982	129,500	25,100	130,200	700
1983	145,700	36,000	154,600	2,300
1984	142,200	42,000	144,700	2,500
1985	135,100	43,800	124,000	1,600
1986	145,600	49,800	125,300	1,900
1987	175,300	62,400	207,300	1,300
1988	149,800	43,100	190,200	1,500
1989	142,100	25,400	227,400	1,200
1990	131,500	17,300	231,100	1,900

[1] Estimates of sturgeon angler trips are unavailable prior to 1974.

[2] Estimates of sublegal and oversized sturgeon handled in the sport fishery are unavailable prior to 1982.

Table 7. Lower Columbia River sport sturgeon catch and effort for the Bonneville, Troutdale-Westport, and estuary areas, 1977-1990 (Melcher and King 1991). Lump sum angler trip estimates were made for winter months prior to 1990 and are only included in the annual totals. Lump sum catch estimates were made for winter months prior to 1982 and are only included in the annual totals.

	Bonneville area (RM 145-127)		Troutdale-Westport (RM 127-38)		Estuary area (RM 38-0)		Lower river total (RM 0-145)	
Year	Trips	Catch	Trips	Catch	Trips	Catch	Trips	Catch
1977	25,472	15,377	14,132	2,788	8,047	4,171	55,100	25,800
1978	41,758	19,958	27,353	5,256	11,517	4,473	82,500	30,400
1979	49,230	18,239	39,906	8,041	9,576	4,442	101,000	31,400
1980	48,350	14,048	40,470	6,059	12,342	5,715	105,900	27,000
1981	48,972	13,549	44,400	6,410	16,977	5,748	116,800	27,200
1982	48,636	11,971	50,185	6,329	20,839	6,758	129,500	25,100
1983	56,578	17,131	52,961	6,740	26,803	12,109	145,700	36,000
1984	50,934	12,865	51,199	7,207	32,455	21,902	142,200	42,000
1985	53,859	15,286	41,133	4,993	37,907	23,543	135,100	43,800
1986	47,223	12,022	41,410	7,663	43,357	30,159	145,600	49,800
1987	61,140	17,714	51,681	7,885	51,907	36,848	175,300	62,400
1988	53,361	14,283	45,436	6,093	40,601	22,755	149,800	43,100
1989	54,759	13,751	37,974	5,219	28,564	6,500	142,100	25,400
1990	50,805	7,949	45,881	1,908	34,779	7,453	131,500	17,300

The fishery in the Bonneville area is comprised of a bank component and a boat component. This is the primary sturgeon bank fishing area on the lower Columbia River. The majority of the sturgeon bank fishing effort in this section occurs in the uppermost three miles of river immediately below Bonneville Dam. Bank angler access is excellent from both the Oregon and Washington shores. The sturgeon bank fishery in this area takes place year-round with peak catches occurring in late spring and early summer. The sturgeon population in this bank fishing area averages larger-sized fish than the rest of the lower river. Sturgeon abundance immediately below the dam may be associated with food availability and spawning.

The sturgeon boat fishery in the Bonneville area also takes place year-round. Peak catches associated with the boat fishery in this area occur during late winter. Good wintertime catches are a result of a large abundance of smelt in the lower Columbia during this time of year. Smelt are a favorite food of white sturgeon. The availability of fresh smelt seems to trigger aggressive feeding behavior, especially among the smaller sturgeon.

The sturgeon sport fishery in the Troutdale-Westport area is primarily a boat fishery. Anglers participate in the fishery year-round, but peak angler effort and catch typically occurs during late winter. Again, smelt run timing plays a significant role in angler success. The sturgeon population in this section of the river seems to be predominately sublegals with a few small, legal-sized fish. The sturgeon bank fishery in this area remains relatively small. Bank angler access to the deepwater areas associated with sturgeon is very limited. Peak bank angler catch and effort in this section of river also typically occur in late winter.

The sport sturgeon fishery in the estuary is almost exclusively a boat fishery. Anglers participate in this fishery primarily during the spring and summer months and effort levels are related to ocean salmon fishing opportunity. Estuary sturgeon angler effort increased dramatically during the mid-1980s as a result of shortened ocean salmon seasons. Estuary sturgeon catch and angler trips dropped in 1989 and 1990 from the levels observed in 1984-1988. This drop was due to the effects of a three-year catch reduction regulation package and increased ocean and Buoy 10 salmon angling opportunity.

Since 1984, the charter boat industry has included estuary sturgeon angling among its activities and has been very successful catching sturgeon and attracting clients. In 1990, the charter boat angler's catch rate was 110% higher than that of the estuary private boat angler. Private boats still accounted for 88% of the estuary angler trips and 77% of the estuary catch. Table 8 presents a comparison of charter and private boat effort and catch in the estuary from 1984-1990.

Table 8. Sturgeon charter and private boat effort and catch in the estuary area on the lower Columbia River, 1990 (monthly and total) and 1984-1989 comparison (Melcher and King 1991). There is no appreciable wintertime catch of sturgeon in the estuary.

Month	Boat trips	Angler trips	White Sturgeon: Sublegal	White Sturgeon: Legal	White Sturgeon: Oversize	White Sturgeon: Sublegal/ legal	Green sturgeon legal catch	White & green legal catch/ angler trip
CHARTER (1990 by month)								
April	19	122	244	13	0	18.77	0	0.11
May	119	860	2,604	403	12	6.46	0	0.47
June	198	1,634	5,649	479	17	11.79	1	0.29
July	93	642	3,131	422	3	7.42	4	0.66
Aug	66	405	1,341	170	0	7.89	3	0.43
Sept	40	256	881	157	0	5.61	7	0.64
Total								
1984[1]	–	–	–	–	–	–	–	–
1985	680	4,958	6,964	5,982	21	1.16	108	1.23
1986	761	5,690	5,117	7,403	39	0.69	94	1.32
1987	832	6,016	7,018	7,423	32	0.95	55	1.24
1988	859	6,160	11,900	5,770	10	2.06	15	0.94
1989	608	4,304	12,569	1,922	10	6.54	14	0.45
1990	535	3,919	13,850	1,644	32	8.42	15	0.42
PRIVATE (1990 by month)								
Feb	90	180	0	0	0	0	0	0
Mar	195	451	9	0	0	0	0	0
Apr	1,222	2,969	6,140	327	0	18.78	0	0.11
May	1,190	3,332	5,928	620	27	9.61	0	0.19
June	2,565	6,874	18,009	1,125	9	16.01	4	0.16
July	2,332	6,296	17,719	1,439	13	12.31	26	0.23
Aug	1,751	4,955	12,586	1,445	5	8.71	25	0.30
Sept	992	2,688	5,616	835	0	6.73	16	0.32
Oct	102	256	0	0	0	–	0	–
Total								
1984	9,529	30,121	41,447	21,700	86	1.91	103	0.72
1985	10,916	31,248	25,077	17,518	120	1.43	425	0.57
1986	12,444	35,676	29,460	22,620	183	1.30	305	0.64
1987	15,173	43,194	50,463	29,346	88	1.72	173	0.68
1988	12,050	32,384	48,585	16,985	127	2.87	126	0.53
1989	8,357	22,002	50,760	4,466	74	11.37	70	0.21
1990	10,442	28,001	66,007	5,791	54	11.40	71	0.21
GRAND TOTAL								
1984	9,529	30,121	41,447	21,700	86	1.91	103	0.72
1985	11,596	36,206	32,041	23,500	141	1.36	533	0.66
1986	13,205	41,366	34,577	39,023	222	1.15	399	0.74
1987	16,005	49,210	57,481	36,769	120	1.56	229	0.75
1988	12,909	38,544	60,485	22,755	137	2.66	141	0.59
1989	8,965	26,306	63,329	6,388	84	9.91	84	0.25
1990	10,977	31,920	79,857	7,435	86	10.74	86	0.23

[1] Initial year, no estimate, but at low level and included in private boat total.

Anglers seek white sturgeon in the Willamette River below Willamette Falls (Bennett and Foster 1991; Table 9). Some sport fishing also occurs in the Cowlitz River. Sport fisheries are not known in other lower Columbia tributaries, such as the Clatskanie, Kalama, Lewis, Sandy, and Washougal rivers; sturgeon are not believed to use these rivers. The Deep and Grays rivers are used by sturgeon (see Section II.B.).

Comparisons of Commercial and Sport Harvest

From 1972-1976, the magnitude of the sport and commercial harvest was similar (ODFW and WDF 1989; Table 5). Since 1973, the number of fish landed in the sport harvest has exceeded the commercial harvest, except for 1976 (ODFW and WDF 1991). Between 1987 and 1989, the angler catch downstream from Bonneville Dam exceeded the commercial harvest, landing 5-7 sturgeon for every commercially landed fish (Tables 5, 10). Yield (weight) of the sport harvest also exceeded the yield (weight) of the commercial harvest.

The numbers of white sturgeon caught in recent years (commercial and sport combined) were similar to the 1892 catch, although biomass was less than one fourth of the 1892 landings. This difference is due to the smaller number of large fish today and regulations excluding larger fish from the catch. The lack of sturgeon information and management's focus on salmon delayed modification of sport harvest regulations until the late 1980s, about 10 years after dramatic increases in angler effort and catch for sturgeon.

The total exploitation rate of lower Columbia River sturgeon was probably 20-40% in 1985-1987 (ODFW and WDF 1989). The 1989 exploitation estimate was 13% for sturgeon 36-72 in (91-183 cm), due to regulations to reduce harvest (J. DeVore, WDF, pers. commun.).

Table 9. Estimated sturgeon angler trips and catch on the lower Willamette River, March through June 1978-1990 (Bennett and Foster 1991).

Year	Boat		Bank		Total	
	Angler trips	Catch	Angler trips	Catch	Angler trips	Catch
1978	2,216	296	--	--	2,216	296
1979	3,253	592	360	15	3,613	607
1980[1]	2,566	204	3,319	126	5,885	330
1981	3,213	275	2,338	126	5,551	401
1982	3,263	293	2,603	151	5,866	444
1983	3,471	163	2,515	103	5,986	266
1984	3,046	74	2,885	120	5,931	194
1985	3,725	205	2,684	107	6,409	312
1986	2,945	265	2,188	114	5,133	379
1987	3,310	353	437	25	3,747	378
1988	2,161	200	1,127	25	3,288	225
1989	1,537	66	715	5	2,252	71
1990	2,749	172	866	9	3,615	181

[1] No estimate of angler trips or catch from April 28 through May 18, 1980.

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Table 10. Columbia River white sturgeon commercial landings (in thousands), 1960-1990 (ODFW and WDF 1991).

	Zones 1-5 (Below Bonneville Dam)		Zone 6 (Bonnev. Dam - McNary Dam		Total (Mouth to McNary Dam)	
Year	Lbs.	Nos.	Lbs.	Nos.	Lbs.	Nos.
1960	173.1	4.3	11.0	0.2	184.1	4.5
1961	174.0	4.4	9.3	0.2	183.3	4.6
1962	196.5	4.9	4.1	0.1	200.6	5.0
1963	207.8	5.2	4.2	0.1	212.0	5.3
1964	135.8	3.4	3.8	0.1	139.6	3.5
1965	150.1	3.8	7.9	0.2	158.0	4.0
1966	221.2	5.5	5.0	0.1	226.2	5.6
1967	151.1	3.8	8.6	0.2	159.7	4.0
1968	141.1	3.5	10.6	0.2	151.7	3.7
1969	293.4	7.5	16.6	0.4	310.0	7.9
1970	250.0	6.3	15.3	0.4	265.3	6.7
1971	280.2	7.2	31.3	0.7	311.5	7.9
1972	297.5	7.6	30.5	0.7	328.0	8.3
1973	389.5	10.7	41.5	1.1	431.0	11.8
1974	345.0	10.7	26.6	0.5	371.6	11.2
1975	454.5	14.0	29.3	0.6	483.8	14.6
1976	732.7	22.8	24.4	0.6	757.1	23.4
1977	320.7	9.7	20.2	0.6	340.9	10.3
1978	288.5	9.8	20.7	0.7	309.2	10.5
1979	533.8	20.5	38.8	1.3	572.6	21.8
1980	263.2	9.4	53.4	1.8	316.6	11.2
1981	419.9	14.9	70.4	2.1	490.3	17.0
1982	353.0	11.6	44.8	1.3	397.8	12.9
1983	398.6	12.4	48.7	1.4	447.3	13.8
1984	524.4	17.5	88.3	2.8	612.7	20.3
1985	270.4	8.4	168.5	5.0	438.9	13.4
1986	374.0	11.6	322.1	9.5	696.1	21.1
1987	307.0	9.7	384.2	11.1	691.2	20.8
1988	216.6	6.9	136.4	4.1	353.0	11.0
1989	161.2	5.0	126.5	3.5	287.7	8.5
1990	175.2	5.2	115.4	3.5	290.6	8.7

Harvest Management Goals

The current management goals for the Columbia River downstream from Bonneville Dam are:

1) To reduce the combined sport and commercial exploitation of the 3-6 ft (91-183 cm) size class to 15% by January 1992 (King 1989).

2) To provide maximum white sturgeon harvest on a sustained basis to both recreational and commercial fishermen (J. DeVore, WDF, pers. commun.).

These goals have been achieved with minimum-size increases and bag-limit reductions for the sport fishery and prohibition of commercial target sturgeon fishing.

In Oregon, the 1989 state Legislature prohibited additional broodstock collection permits for commercial aquaculture, beyond the two companies with previous permits, due to political pressure from commercial harvest interests.

C. COLUMBIA RIVER UP TO CHIEF JOSEPH DAM AND THE LOWER SNAKE RIVER TO LOWER GRANITE DAM

The Columbia River between Bonneville and both Chief Joseph and Lower Granite dams consists of several management units: (1) the three pools between Bonneville and McNary dams that are known as Zone 6, (2) McNary Pool and the Columbia River upstream from McNary Pool to Chief Joseph Dam, and (3) the Snake River from Ice Harbor Dam upstream to Lower Granite Dam.

History of Commercial and Treaty Fishing in Zone 6, Between Bonneville and McNary Dams

The white sturgeon population was probably still recovering from the overharvest of the 1890s when Bonneville Dam was constructed in 1937-1938. At the time of Bonneville Dam's construction, white sturgeon had access upstream in the Columbia River to Rock Island Dam and upstream in the Snake River to Swan Falls Dam.

Until the completion of The Dalles Dam in 1957, there was a non-treaty commercial fishery up to a deadline at the mouth of the Deschutes River, above Celilo Falls. Fishermen targeted white sturgeon with setlines within the seasons and gear restrictions enacted by the Columbia River Compact. Sturgeon were also taken as an incidental species during salmon gill-net seasons. Annual commercial landings of white sturgeon in Zone 6 from 1938-1956 ranged between 16,300 lb and 187,300 lb (7,400-85,034 kg). In comparison, the commercial landings in Zones 1-5 (downstream from Bonneville Dam) were usually larger, ranging from 28,500-388,100 lb (12,939-176,197 kg) annually for the same period (Table 4; Figure 12).

Commercial fishing by non-treaty fishermen in the Columbia River upstream from Bonneville Dam was prohibited by Oregon and Washington state regulations in 1957. Sport fishing continued, but probably did not take many sturgeon in the early years. Annual landings of 3,800-35,900 lb (1,725-16,299 kg) of white sturgeon were recorded for the commercial fishery (setnets and setlines) in Zone 6 between 1958 and 1967. (Tables 4, 10; Figures 13, 14).

By 1968, treaty fishermen had increased their efforts to catch salmon in Zone 6. Conflict over state regulations promulgated by the WDF and ODFW to regulate treaty Indian fisheries for salmon and steelhead led to the court case United States v. Oregon, which affirmed treaty-reserved fishing rights of the four treaty tribes. The case also led to the adoption of the Columbia River Fish Management Plan in 1988. The details of the salmon and steelhead regulations are beyond the scope of this document. However, the salmon and steelhead harvest regulations influence the incidental harvest of white sturgeon in Zone 6.

From 1968-1975, the primary gear type used during the salmon and steelhead seasons was the anchored gill net (setnet), however, the use of the sturgeon setline was also legal. Sturgeon caught incidentally on either gear during open commercial salmon and steelhead seasons could be sold. The sturgeon catch record did not include gear type prior to 1976, but the majority was incidental to salmon setnet fishing. The commercial treaty harvest of white sturgeon during this period ranged from 10,600-41,500 lb (4,812-18,841 kg) annually, representing 200-1,100 fish (Table 10; Figure 14).

Separate seasons for treaty commercial setlines targeting sturgeon began in 1976 (Appendix Table C3a). Initially the setline seasons were three and four months long in 1976 and 1977, respectively; in 1978 and 1979, the setline season was seven months long. The total treaty sturgeon harvest from 1976-1979 was relatively stable at 600-1,300 white sturgeon (20,200-38,800 lb; 9,171-17,615 kg) annually (Table 10; Figure 14). Similar numbers of fish were taken with each gear type (Table 5).

From 1980-1987, setline seasons were open for 9-10 months per year with closures from May to July. As early as 1984, a few treaty fishermen began using large mesh sunken (diver) nets during the salmon and steelhead setnet season, rather than the usual floater nets, to target sturgeon. The diver nets succeeded in catching not only sturgeon, but upriver bright fall chinook salmon, thus proliferating their use (J. DeVore, WDF, pers. commun.). The use of diver nets dramatically increased the sturgeon catch for those fishermen (D. Swartz, ODFW, pers. commun.). Diver-net use increased over the next several years.

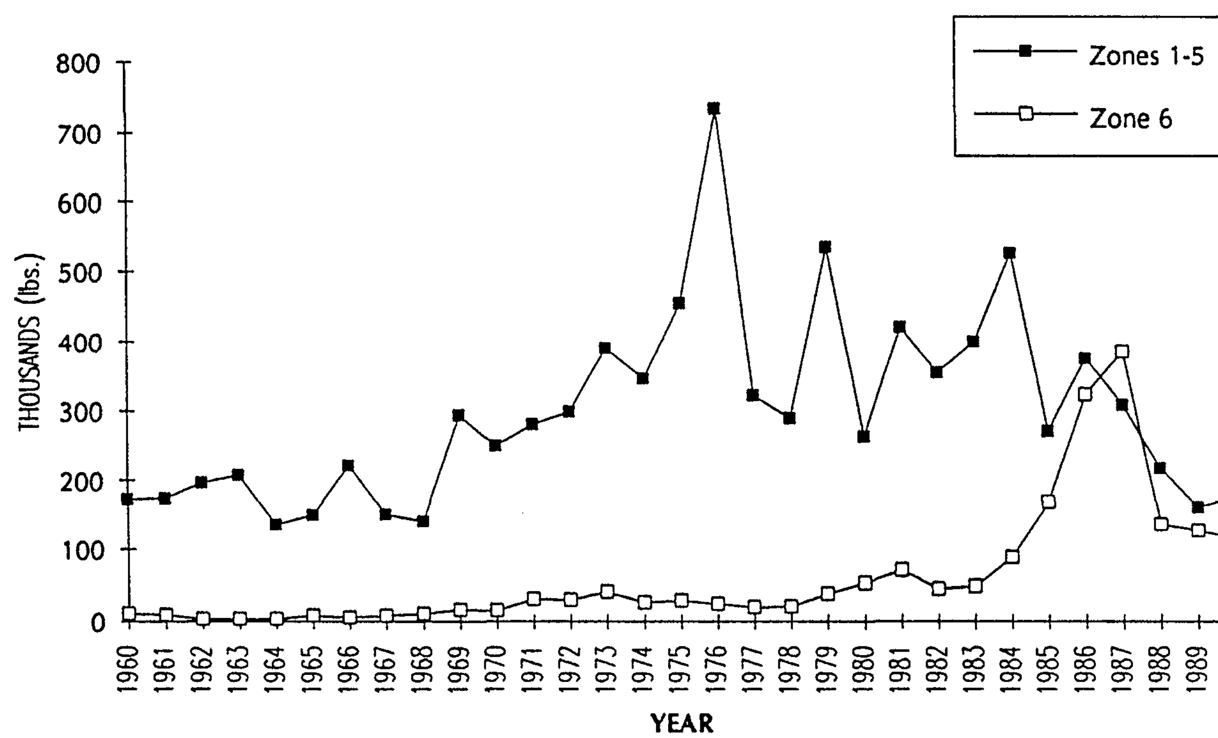

Figure 14. Estimated commercial harvest (in lb) of white sturgeon from the Columbia River from 1960-1990 (ODFW and WDF 1991).

When diver nets proliferated and the setline seasons were extended to 9-10 months per year in the early 1980s, the total Zone 6 commercial catch increased. From 1980-1983 total catch ranged from 1,300-2,100 sturgeon per year and 82% of the fish were taken on setlines (Tables 5, 10; Figure 14). At the same time, salmon and steelhead setnet seasons were reduced due to poor salmon and steelhead runs.

More liberal setnet seasons occurred with the improved fall salmon and steelhead runs in 1984 through 1987 (D. Swartz, ODFW, pers. commun.). These seasons were accompanied by an increased incidental sturgeon catch. Treaty sturgeon catch increased from 2,800 fish in 1984 to 11,100 fish in 1987. The annual biomass harvested was 88,300-384,200 lb (40,088-174,427 kg) during the period (Table 10; Figure 14). About 64% of the sturgeon catch was from gill nets (Table 5).

In 1988 the tribes, Oregon, and Washington, through the Sturgeon Management Task Force (SMTF), reviewed the status of white sturgeon and provided harvest management recommendations (see Sections IV.A. and IV.C.). The task force recommended to the Columbia River Compact reductions in commercial sturgeon harvest (incidental and directed harvest combined) and a 1988 harvest guideline of a 22-25% cutback from the 1985-1987 average. The actual 1988 catch was 4,100 fish. The SMTF also recommended reductions in the sport fishery. The 1989 and 1990 guideline was not to exceed the 1988 catch level of 4,100 fish. Tribal harvest was well below the harvest guideline in 1989 and 1990, due to a combination of tribal regulations and declining abundance (S. Parker, YIN, pers. commun.).

For 1991, SMTF negotiations, based on preliminary research data from the Bonneville Power Administration-funded research effort, produced a management strategy of shared treaty/non-treaty impacts of 15%, 10%, and 10% harvest rates for the 3-6 ft populations in Bonneville, The Dalles and John Day pools, respectively. The task force also recommended shared reductions in both the recreational and commercial fisheries in Zone 6 based on the 1989-1990 average catch percentages. Commercial catch reductions took the form of harvest guidelines for each pool (Bonneville, 1,250 fish; The Dalles, 300; and John Day, 100; see Appendix Table C3a). Recreational catch reductions were achieved in April 1991 by enacting a 48-66 in TL size slot limit and a one-fish daily bag limit for all areas upstream from The Dalles Dam. A one-fish, $<$48-in and one-fish, $\geq$48-in daily bag limit was enacted for the Bonneville Pool recreational fishery to achieve the SMTF harvest guidelines for that pool.

Native Americans may also retain sturgeon (within legal size limits) taken on commercial gear for subsistence purposes. Each tribe provides its own regulations for this fishery. There are no records for this harvest, and it is not associated with the commercial harvest target. Sanctuary zones at dams restricting subsistence fishing are smaller than those for commercial fishing.

History of Recreational Fishing Between Bonneville and McNary Dams (Zone 6)

Prior to April 1991, sport anglers could take 2 fish/day, one fish 40-48 in (102-122 cm) and one fish $\geq$ 48 in (122-183 cm) TL, and 15 fish/year. In April 1991, for all areas upstream from The Dalles Dam, the daily bag limit became one fish, 48-66 in (122-168 cm) TL. Prior to April 1988, the minimum size limit in Zone 6 was 36 in (91 cm) TL. Use of gaffs and barbed hooks is illegal, and the season is open year-round, but angling is prohibited in sanctuary zones in the tailrace of each dam. Sanctuary zones are larger (more restrictive) for boat anglers than for bank anglers. Since 1988, the SMTF provided recommendations for sport harvest management strategies to the ODFW and WDF.

In 1988 and 1989, sturgeon anglers represented 32% and 46%, respectively, of the sport fishing effort in Bonneville Pool from March to October (LaVoy et al. 1989; DeVore et al. 1990). Only 0.5% of the sturgeon were taken by anglers seeking other species (LaVoy et al. 1989; DeVore et al. 1990). About 10 sublegal fish and one oversized fish were handled for every two legal fish taken (LaVoy et al. 1989). In Bonneville Pool, anglers spent more time fishing for sturgeon in 1989 (70,000 hr) than in 1988 (42,000 hr) and caught more than twice as many fish (2,600 versus 1,100 fish; LaVoy et al. 1989; DeVore et al. 1990). The CPUE for sturgeon fishermen in Bonneville Pool was about 0.03 fish/hr in 1988 and about 0.04 fish/hr in 1989 (LaVoy et al. 1989; DeVore et al. 1990).

Sturgeon anglers expended similar effort in The Dalles Pool in 1988 and 1989, but represented a smaller proportion of the total effort in 1989 (25%) than in 1988 (41%) (LaVoy et al. 1989; DeVore et al. 1990). The ratio of sublegal:legal:oversized fish in the catch was about 25:5:1. Only 2% of the sturgeon were taken by anglers seeking other species. The CPUE was about 0.01 fish/hr in 1988 and 1989 (LaVoy et al. 1989; DeVore et al. 1990).

From 1983-1986, sturgeon anglers represented 45-67% of the total sport fishing effort expended on John Day Pool. Sturgeon anglers spent almost 50,000 hours fishing each year on John Day Pool and caught about 700-1,700 sturgeon each year. The overall CPUE in 1983 (0.06 fish/hr) was at least twice as large as the CPUEs for 1984 (0.02 fish/hr), 1985 (0.03 fish/hr), and 1986 (0.02 fish/hr; calculated from data in Beamesderfer et al. 1990b).

In 1989, sturgeon anglers represented 30% of the angler effort on John Day Pool, but only 10% fewer angler hours than during 1983-1986. About 60-80% fewer sturgeon were caught by sportsmen in 1989 than during 1983-1986. CPUE also declined to <0.01 fish/hr in 1989 (DeVore et al. 1990).

Comparison of Commercial and Recreational Harvest in Zone 6

Although commercial fishery statistics exist, long-term creel census data are not available for sturgeon sport fisheries between Bonneville and McNary dams. Recent studies provide some sport harvest data for the mid- to late 1980s, allowing limited comparisons with the commercial fishery. The sport fishery in Zone 6 took an estimated 5,000 sturgeon annually from 1980-1987. This is about one sturgeon per 10 angler trips (LaVoy 1989). During the same period, the annual commercial harvest of white sturgeon in Zone 6 was between 1,400 and 11,100 fish (Table 10; Figure 14).

Exploitation rates in The Dalles Pool during 1987 were 0.06-0.09 (May-October) for sport harvest and about 0.29 (July-December) for commercial harvest (Nigro et al. 1988). However, the sport and commercial fisheries had different size limits, and thus each affected the sturgeon population differently.

Anglers caught about 50% of the 1989 estimated sturgeon harvest in Zone 6 (DeVore et al. 1990). The distribution of the harvest varied, with anglers taking most of the total catches in the Bonneville and John Day pools (63-65%; DeVore et al. 1990). In The Dalles Pool, the situation was just the opposite, with commercial harvest representing 79% of the total catch (DeVore et al. 1990).

Fishing Upstream from McNary Dam

Data describing the sturgeon fishery upstream from McNary Dam to either Chief Joseph Dam or Lower Granite Dam are sparse. Commercial sale of sturgeon taken upstream from McNary Pool is prohibited (S. Parker, YIN, pers. commun.). Washington sportsmen take a few fish each year (see Section II.C.), but CPUE and exploitation rates are not available. Since 1986, a minor treaty salmon gill-net fishery in Priest Rapids Pool has taken small numbers (6-18) of relatively large (>50 lb; >22.7 kg) white sturgeon (J. DeVore, WDF, pers. commun.; S. Parker, YIN, pers. commun.). The fishery in the Snake River between Ice Harbor and Lower Granite dams is relatively minor and entirely a sport fishery. Anglers take a few fish annually from each of the three Snake River pools (see Section II.C.), but CPUE and exploitation estimates are unavailable.

Current Management Goals

Until 1991, management goals for Zone 6 did not address total exploitation, rather they hoped to reduce harvest by a particular percentage. In 1991, management goals for Zone 6 were set to achieve 15% exploitation in Bonneville Pool and 10% exploitation in The Dalles and John Day pools. The long-term management objective is to reduce exploitation to sustainable yields (J. DeVore, WDF, pers. commun.). Ongoing studies are attempting to estimate current exploitation rates in the three pools of Zone 6. Theoretical modeling simulations provide information on estimates of sustainable exploitation, maximum sustainable yield, exploitation rates that could potentially collapse the population, and evaluations of several harvest regulation strategies (see Section I.E.). The pools between McNary Dam and either Chief Joseph or Lower Granite Dam have not been modeled.

Management goals for sturgeon populations in the Columbia River between McNary and Chief Joseph dams have not been formulated. As of April 16, 1991, all areas upstream from The Dalles Dam have a one-fish daily bag limit and a 48-66 in size limit for recreational fisheries (Appendix Tables C3b, C4). Sturgeon in the Hanford reach are incidentally protected by a seasonal fishing closure (October 23 to June 15) designed to protect waterfowl; there are no seasonal closures for sturgeon elsewhere along the Columbia River in Washington (J. DeVore, WDF, pers. commun.; D. Swartz, ODFW, pers. commun.).

D. COLUMBIA RIVER BASIN UPSTREAM FROM CHIEF JOSEPH DAM

History of Fishing

Information concerning exploitation of white sturgeon in the Columbia River Basin upstream from Chief Joseph Dam during the 1800s is unavailable. In more recent times, sport and subsistence fishing occurred in the upper Columbia River in Washington and Canada. There are no long-term data to describe the history of the fishery or to estimate current harvest and exploitation.

There is no evidence of sturgeon exploitation in the Kootenai River Basin in the 1800s. Sturgeon setlines and burbot anglers harvested sturgeon downstream from Kootenai Falls in the 1940s and 1950s (Graham and White 1984). The burbot population and sturgeon harvest declined in the 1950s and 1960s (Graham and White 1984). The sturgeon population changes coincided with changes in water quality and land use, as well as burbot abundance and harvest. During the early and mid-1980s, Idaho biologists became concerned about the status of the sturgeon population. Idaho regulations limited the fishery to catch and release in 1984. In 1989, British Columbia adopted catch-and-release regulations in the Kootenai River Basin. Today there are no commercial fisheries in the U.S. or Canadian portions of the Kootenai River Basin.

Harvest Management Goals for the Kootenai River

The regulatory agencies responsible for the Kootenai River Basin have not established common management goals for white sturgeon. However, the IDFG goal is to "enhance white sturgeon populations in the Kootenai" (IDFG 1990). Montana does not have specific white sturgeon management goals (S. Rumsey; Montana Department of Fish, Wildlife and Parks; pers. commun.). British Columbia is developing management goals for white sturgeon throughout the province (J. Hammond, BCMEP, pers. commun.).

Several agencies have classifications for white sturgeon that potentially influence management. Montana has considered the white sturgeon a "sensitive species" since 1979. The U.S. Forest Service and Bureau of Land Management classify the white sturgeon as a sensitive species (Mosley and Groves 1990). The Canadian government considers white sturgeon a vulnerable species, while Idaho considers the white sturgeon a species of special concern (Mosley and Groves 1990). The IDFG recently requested that the U.S. Fish and Wildlife Service include the Kootenai River white sturgeon in the annual review of candidate species for classification under the Endangered Species Act (IDFG letter to USFWS dated September 1990). Apperson and Anders (1990) recommended considering the Kootenai River white sturgeon for federally threatened or endangered species classification.

E. MAINSTEM SNAKE RIVER UPSTREAM FROM LOWER GRANITE DAM

History of Fishing

Commercial fishing for sturgeon in Idaho began as early as the mid-1890s. Commercial and sport fishing in Idaho was not regulated until 1943, when commercial fishing was prohibited. At that time, sport harvest limits were set at 2 fish/day and two fish in possession. The fishing regulations became more restrictive every 2-5 years between 1943 and 1960 (Appendix Table C5). Setlines became illegal in 1956. Regulations became more structured and therefore more difficult to enforce in the 1960s. Regulations limited sport gear type, size of fish taken, and annual harvest, but allowed more fish in possession.

Sturgeon angling became a catch-and-release fishery throughout the Snake River in 1970. Shortly afterward, Idaho classified white sturgeon as a species of special concern (Mosley and Groves 1990). The Bureau of Land Management considers the white sturgeon a sensitive species, while the USFWS (Region 1) considers the Snake River sturgeon a species in its "to watch" category (Mosley and Groves 1990).

Current Recreational Harvest Management Goals

All sections of the river are open to catch-and-release sturgeon fishing. Five years ago, Cochnauer et al. (1985) recommended closing three sections of the Snake River to fishing: (1) Brownlee Dam to Swan Falls Dam, (2) Swan Falls Dam to C.J. Strike Dam, and (3) Bliss Dam to Shoshone Falls.

Idaho's statewide sturgeon management goal is to preserve, restore, and enhance viable white sturgeon populations capable of providing sport fishing opportunity. The IDFG's five-year plan (1990-1995) includes specific management directions for isolated populations in the Snake River:

1) The IDFG goal is to preserve the white sturgeon population between Hells Canyon and Lower Granite dams and in the Salmon River, a tributary to the Snake River (IDFG 1990). The IDFG plans to maintain the non-consumptive fishery, but may take actions to reduce sportsmen disturbance of spawning sturgeon and to reduce hooking mortality (IDFG 1990).

2) The IDFG goal is to increase the abundance of white sturgeon between Hells Canyon and C.J. Strike dams (IDFG 1990). The non-consumptive fishery will continue (IDFG 1990), and improved angler access is planned between Loveridge Bridge and Bliss Dam (IDFG 1990). The IDFG efforts will also focus on the preservation (and perhaps enhancement) of sturgeon habitat (IDFG 1990; B. Horton, IDFG, pers. commun.). Although the five-year plan implies a supplementation program, such programs are experimental and are not expected to produce consumptive fisheries (Cochnauer, IDFG, pers. commun.; S. Huffaker, IDFG, pers. commun.).

3) The IDFG will maintain the non-consumptive fishery for white sturgeon upstream from C.J. Strike Dam to Shoshone Falls and conduct experimental releases of white sturgeon.

F. FRASER RIVER

History of Fishing

Native Americans harvested sturgeon in the Fraser River for food and trade. They traded a type of isinglass (a gelatin made from the lining of the air bladder) with the Hudson Bay Company until 1866 (Semakula 1963).

Commercial fishing began after caviar and smoked sturgeon became popular in the United States. Sturgeon were caught incidentally in salmon nets by 1886 (Parks 1978) and became an important part of the fishing industry by 1897. About 8,000 lb (3.6 t) of sturgeon were harvested between 1880 and 1890 (Swiatkiewicz 1989). The catch declined 20% by 1900, and 93% by 1905. The catch was only 2,000 lb (0.9 t) between 1910 and 1920, when the population collapsed.

By 1911 there were season, fish size, and gear type regulations pertaining to Fraser River sturgeon (Parks 1978). When the population continued to decline, fish size limitations became more restrictive (Parks 1978). Incidental commercial harvest of white sturgeon continued in the salmon gill-net fishery.

The following data were compiled recently and provided by D. Lane of Malespina College in Nanaimo, British Columbia. Landings ranged from 1,800 to 67,000 lb (0.8-30 t) annually from 1953-1980. The CPUE for this period was impossible to interpret because the definition of amount of effort varied.

Changes in salmon regulations reduced the non-treaty commercial harvest of sturgeon in 1981. Commercial non-treaty landings from 1981-1989 ranged from 224-2,000 lb (0.1-0.9 t). Treaty landings from the Native American food fishery were between 2,240 lb and 4,480 lb (1-2 t) from 1983-1988, and increased to 12,000 lb (5.4 t) in 1988.

Interest in sport fishing for sturgeon increased during the 1970s (Swiatkiewicz 1989).

Canadian sport and commercial fisheries are managed by river sections under the direction of federal and provincial governments -- the Canadian Department of Fisheries and Oceans and the BCMEP, respectively. Currently, there are four provincial regions and one federally managed region in the basin:

1) The upper Fraser River Basin from the headwaters to the community of Cottonwood, known as the Omineca region.

2) The basin from Cottonwood to the Nicola River, known as the Caribou region.

3) The basin from the Nicola River to Hells Gate.

4) The basin between Hells Gate and Mission Bridge.

5) The basin downstream from the Mission Bridge to and including coastal waters.

The semi-anadromous population downstream from Hells Gate provides the majority of the white sturgeon harvest in the Fraser River Basin. It is accessible to fishermen as the largest population centers in the province border this region. About 30-50 lb (13.6-22.7 kg) of sturgeon are landed annually in the salmon fishery (Swiatkiewicz 1989). Annually, anglers catch about 4,000 sturgeon, but keep 925; angler interest in catch and release is growing (Swiatkiewicz 1989). The Native American fishery harvests sturgeon incidental to salmon gill netting downstream from Hells Gate. The regulations for both management areas include a minimum size limit of 39 in (100 cm) TL. The area upstream from Mission Bridge has a maximum size limit of 79 in (200 cm), while the area downstream from Mission Bridge has no maximum size limit.

White sturgeon harvest occurs throughout the Fraser River upstream from Hells Gate. Since 1986, sport regulations included a 39-in (100 cm) minimum length, a maximum size of 79 in (200 cm), and a 1 fish/day limit (Dixon 1986). Harvest, yield, and other fisheries data are not available.

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The Omineca region (the headwaters to Cottonwood) includes the Nechako and Stuart River basins. Sturgeon are taken in a sport fishery, Native American salmon gill-net fishery, and a target Native American fishery. Sport fishing regulations in 1986 included a 39-in (100 cm) minimum length, a 79-in (200 cm) maximum length, and 1 fish/year limit (Dixon 1986). The sport fishery is a setline permit fishery that yields 1-12 fish per year (Dixon 1986). The Native American salmon fishery intercepts approximately 10-25 sturgeon per year (882-3,087 lb/year; 400-1400 kg/year). The region included in this estimate includes 74.6 miles (120 km) of the Nechako River and 37.3 miles (60 km) of the Fraser River near the confluence with the Nechako. There are no records for the target sturgeon fishery.

Swiatkiewicz (1989) considers 10% total annual mortality (exploitation and natural mortality) too high to sustain Fraser River populations. Dixon (1986) suggested that 5% per year is excessive, based on discussions in Ricker (1963) and Semakula (1963).

Current Harvest Management Goals

British Columbia biologists are developing provincewide policies and goals for white sturgeon management. They expect to terminate the free permit program and recommend a provincial license; the money would be used for sturgeon research (D. Cadden, BCMEP, pers. commun.). They also anticipate standardizing size limits by instituting a maximum length throughout the Fraser River Basin.

The federal government considers the white sturgeon a vulnerable species (D. Lane, Malespina College, pers. commun.), based on its limited distribution in Canada (Lane 1987).

G. PACIFIC COAST AND COASTAL RIVERS

History of Fishing in Estuaries and Marine Waters

California does not permit the commercial harvest of sturgeon in marine waters. However, sturgeon may be taken incidentally in the ocean by sports fishermen and, rarely, spear fisheries (D. Kohlhorst, CDFG, pers. commun.).

The Oregon coast sturgeon fisheries are in nearshore areas and within the tidewater of bays or rivers. There are no tribal fisheries for sturgeon on the Oregon coast. Commercial trawl fishing takes some sturgeon in nearshore areas. One commercial trawl fisherman tagged and released 150 sublegal sturgeon during 1987. The sport season is open all year for sturgeon between 40 in and 72 in (102-183 cm). The creel limit is 2 fish/day (one fish 40-48 in and one fish 48-72 in), 6 fish/week, and 15 fish/year. Sturgeon are caught in most Oregon estuaries with the largest fisheries located in Umpqua and Tillamook bays.

Some white sturgeon are taken incidental to commercial groundfish trawling operations along the Oregon and Washington coasts (Table 11). Most of the white sturgeon taken in the marine trawl fishery are taken adjacent to the Columbia River. Most of these fish are opportunistically targeted; that is, when the trawling operations find white sturgeon, they take them. The majority of white sturgeon are landed in Astoria, Oregon, and Ilwaco, Washington. Commercial operators landing at Coos Bay and the Umpqua River captured and returned white sturgeon that had been marked in the Columbia River in 1987.

Table 11. Washington and Oregon landings of white sturgeon (in lb) in the ocean trawl fishery, 1981-90 (ODFW, unpublished data).

Year	Washington	Oregon	Total
1981	1,444	2,373	3,817
1982	2,659	3,915	6,574
1983	766	2,806	3,572
1984	350	23,415	23,765
1985	6,489	15,649	22,138
1986	5,945	3,368	9,313
1987	709	5,636	6,345
1988	125	3,770	3,895
1989	234	478	712
1990	2,106	10,768	12,874

Commercial catch of white sturgeon occurs in Willapa Bay, Grays Harbor, and Puget Sound (Parks 1978; Boomer and Joner 1989). The Puget Sound catch is a treaty fishery; non-treaty commercial sturgeon fishing is illegal there. Currently, commercial retention of white sturgeon is legal for all Washington coastal areas.

The Chehalis Tribe's subsistence setnet fishery for salmon and sturgeon in Willapa Bay began in 1979 after negotiations with the WDF (Boomer and Joner 1989). Some commercial landings occurred in this fishery prior to the 1979 agreement (1940-1979). Today incidental sturgeon harvest occurs during the chinook salmon season (May-August). The non-treaty gill-net season for chinook salmon used to begin on July 1, but it is uncommon for chinook salmon to arrive until mid-July. In effect, fishermen actively sought sturgeon (WDF inter-office memorandum from Schaefer to Stone dated December 21, 1987). The 1988 catch in Willapa Bay was 750 white sturgeon (approximate 10-year average). The

1989 and 1990 treaty fishery regulations required the release of all white sturgeon caught incidentally in gill nets during July.

The incidental harvest of white sturgeon has a similar history in Grays Harbor. In 1988 the white sturgeon catch was 690 fish (90% of the 10-year average). The 1989 and 1990 regulations required the release of all white sturgeon caught incidentally in gill nets during July.

Sturgeon harvest in Puget Sound is primarily incidental to groundfish otter trawling (Parks 1978). Gill nets and purse seines take some white sturgeon, but none may be kept by non-treaty fishermen in Puget Sound (Parks 1978; J. DeVore, WDF, pers. commun.). Setlines are now illegal in the sound, but were once used in large numbers. Tribes in the Puget Sound area also report a minor catch of sturgeon incidental to the chinook salmon gill-net fisheries (Boomer and Joner 1989).

History of Fishing in Coastal Rivers and Bays

Commercial and Subsistence Fishing

Incidental harvest of white sturgeon occurs in the tribal salmon subsistence fisheries of the Klamath/Trinity River Basin. The white sturgeon catch is small, which probably reflects their low abundance.

The U.S. Fish and Wildlife Service has monitored the Indian subsistence harvest of spring and fall chinook salmon on the Hoopa Valley Indian Reservation from 1978-1983. These fisheries also harvest green and white sturgeon incidentally. In 1983, the Hoopa Valley Business Council Fisheries Department assumed monitoring of the Indian harvest in the Trinity River portion of the reservation, while USFWS monitoring efforts (from 1983 to present) focused on the Klamath River portion of the reservation. In 1988, congressional action separated the Klamath River portion of the Hoopa Valley Indian Reservation, thereby creating the Yurok Indian Reservation.

The USFWS and CDFG also conducted beach seine sampling for adult salmonids from 1979-1990 near the mouth of the Klamath River and captured green sturgeon and occasionally white sturgeon. The Hoopa Valley Indian Reservation monitors the tribal fisheries in the Trinity River within their jurisdictional boundaries. These are the only management programs that either capture or monitor the harvest of white sturgeon within the Klamath/Trinity River Basin (J. Polos, USFWS, pers. commun.).

Native Americans use gill nets with 8-9 in (20.3-22.9 cm) stretched mesh when specifically targeting sturgeon. Typically, mesh sizes of 7-7.5 in (17.8-19.1 cm) are most frequently used to target spring and fall chinook salmon (J. Polos, USFWS, pers. commun.). The estimated annual white sturgeon harvest in the Hoopa Valley Indian Reservation was 12-15 fish between 1980 and 1983 (Adair et al. 1984). From 1984-1988 the estimated white sturgeon harvest was 0-3 fish annually in the entire reservation (prior to the formation of the Yurok Reservation; Tuss et al. 1989). The 1989 harvest estimate for the Yurok Indian Reservation was 34 white sturgeon (Kisanuki et al. 1991). White sturgeon were not observed by the USFWS during the 1990 spring and fall monitoring programs (USFWS, unpublished data). These harvest estimates are not the total numbers of sturgeon harvested by the Yurok Indian Reservation gill-net fisheries because an unknown level of sturgeon harvest occurred prior to commencement of the USFWS spring chinook monitoring program (J. Polos, USFWS, pers. commun.). Sturgeon may not be sold commercially in the Yurok or Hoopa Valley Indian reservations.

Ceremonial fishing specifically for sturgeon by Indian peoples is not known in the two reservations (R. McCovey, Yurok Transitional Team, pers. commun.). No data were available to document Native American fisheries in Oregon's coastal rivers.

In Washington, some commercial treaty harvest occurs in the Chehalis, Humptulips, Hoh, and Quinault rivers (J. DeVore, WDF, pers. commun.).

Sport Fishing

Sport harvest occurs in coastal rivers, including the Klamath, Rogue, Umpqua, Yaquina, Nehalem, Tillamook, Nestucca, Siletz, Alsea, Siuslaw, Coos, Chetco, Chehalis, and Humptulips rivers. About 2,000 white sturgeon were taken annually between 1986 and 1990 in Oregon's coastal rivers (ODFW, unpublished data; Table 12). In 1988, about 600 and 1,400 white sturgeon were taken in Washington's Willapa Bay and Grays Harbor, respectively. There are no estimates of total sport harvest in the coastal rivers of California.

Washington's and Oregon's white sturgeon anglers must be licensed and record their catch on catch records. Barbed hooks and night fishing are illegal for all Oregon waters; the use of gaffs is prohibited. The season is open year-round, and bag limits vary between basins. The Rogue River supports guided and individual angler sport fisheries for white sturgeon. The bag limit is 1 sturgeon/day and 15 sturgeon/year. On other Oregon estuaries, sport regulations permit 2 sturgeon/day, 6/week, and 15/year.

Access is available to all popular holes in the Yaquina River Basin, and anglers fish from boats or the banks (ODFW, unpublished data). Yaquina Bay anglers caught 0.04 white sturgeon/hr and 0.16 white sturgeon/angler in 1989; about 80% of the anglers fished from a boat (ODFW, unpublished data). Boat anglers were more successful (0.08 fish/hr) than bank anglers (0.02 fish/angler; ODFW, unpublished data). Between 1980 and 1985, the annual harvest exploitation rate was about 36% (ODFW, unpublished data).

The success of Umpqua River white sturgeon anglers declined in recent years (Johnson 1988). In the early 1960s (1961-1966), anglers caught 0.10 fish/hr. Between 1978 and 1981, anglers caught 0.05 fish/hr (0.03-0.08 fish/hr). More recently (1982-1988), the angler success rate was only 0.03 fish/hr.

Table 12. Estimated sport catch of white and green sturgeon in Oregon coastal rivers and bays, 1986-1990 (based on returned sturgeon catch records).

	White sturgeon					Green sturgeon				
River system	1986	1987	1988	1989	1990	1986	1987	1988	1989	1990
Nehalem	0	47	31	65	115	0	29	21	17	6
Tillamook	542	411	1,049	553	270	25	12	43	0	6
Nestucca	6	12	4	0	0	0	0	0	0	0
Siletz	31	52	9	0	0	25	6	9	0	0
Yaquina	275	331	233	335	133	0	0	26	21	3
Alsea	43	116	26	17	31	0	0	0	17	3
Suislaw	12	6	17	13	100	6	6	0	0	3
Umpqua	646	411	293	494	476	85	70	99	103	109
Coos	37	64	121	124	45	6	6	4	0	3
Coquille	0	17	82	17	9	0	0	0	0	0
Rogue	43	191	73	26	21	6	41	56	35	24
Chetco	19	23	13	17	0	0	0	0	9	0
Total	1,645	1,681	1,951	1,661	1,196	153	170	258	202	157

Sportsmen seek white sturgeon in the Rogue River from the mouth to RM 44 in the "canyon" and in the Illinois River upstream about 5.6 miles (T. Satterthwaite, ODFW, pers. commun.). Most anglers fish the deeper pools to catch large fish. Few sublegal white sturgeon are caught (ODFW, unpublished data).

In 1989, Tillamook Bay white sturgeon anglers hooked 0.05 fish/hr and 0.18 fish/angler. About 75% of the anglers fished from boats. The white sturgeon landed were 36-50 in (91-127 cm) TL (ODFW, unpublished data).

Small sport fisheries occur at the junction of North Slough, South Slough, and Isthmus Slough, and in the Coos River below the confluence of the South Fork Coos River and Millicoma River (Reimers et al. 1990).

Sport harvest and illegal snag fisheries take sturgeon in the Klamath River. The magnitude of this sturgeon harvest and the proportion that is white sturgeon are unknown. Adair et al. (1983) reported legal hook-and-line harvest of sturgeon in the Klamath River near Bluff Creek (RM 47). This fishery occurs in the fall, primarily during October. The extent of this legal sport fishery is unknown. There is an illegal snag fishery in the Klamath River taking sturgeon at Coon Creek Falls (RM 35). The fishery occurs at a large debris jam. A slide created the debris dam in 1977, an assumed obstacle to sturgeon migration. In 1981, dynamite was used to modify the jam, facilitating sturgeon passage. When the debris dam was intact, several hundred fish (assumed to be primarily green sturgeon) per year were snagged. After blasting the debris dam, the illegal fishery declined to <100 fish, the equivalent of about 5-10% of the estimated subsistence harvest of white and green sturgeon (Adair et al. 1983). Present illegal harvest levels at the falls are unknown, but presumed to be low, due to increased enforcement.

<u>Current Harvest Management Goals for the Pacific Coast and Coastal Rivers</u>

Management goal statements have not been formulated for Pacific waters. The sturgeon sport fisheries in Willapa Bay, Grays Harbor, and coastal rivers require a sport punch card and have a slot size limit for sturgeon of 40-72 in (102-183 cm) TL.

In Yaquina Bay, white sturgeon will be managed under Option A of the Oregon Wild Fish Management Policy, which has the objective of maintaining harvest of transient fish in the bay.

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VI. STURGEON ENHANCEMENT AND AQUACULTURE

Enhancement, for the purposes of this document, includes any activity that attempts to increase white sturgeon abundance, except for the control of exploitation (see Section V).

Enhancement programs traditionally attempt to increase the number of fish available for harvest via aquaculture or habitat improvement. Knowledge of habitat requirements suitable for designing enhancement projects is not available. Early attempts in the late 1800s and early 1900s to culture sturgeon in the United States were unsuccessful. The first successful white sturgeon culture facilities were developed during the 1980s (Doroshov et al. 1983).

The successful culture of white sturgeon is the result of 100 years of Soviet research and culture of other sturgeon species (Doroshov and Binkowski 1985) and the efforts at the University of California at Davis. The university began developing propagation techniques for white sturgeon in 1980. Commercial sturgeon facilities were developed in California within two years. Gamete collection programs began in Oregon in the early 1980s. There are commercial grow-out facilities in Washington and culture facilities in Oregon; British Columbia and Idaho do not have commercial culture programs, but expect future interest. At least one commercial aquaculture facility in Idaho has sturgeon, as it is assisting the Fish and Game Department in a culture research project. This facility may be able to achieve Idaho's requirement to use inbasin, domestic broodstock in the future. British Columbia favors sturgeon commercial culture and may become the next major center if reasonably warm water is available.

Both research and commercial growers collect gametes from wild adults in the Sacramento, San Joaquin, and Columbia rivers and San Francisco Bay. Angling is the primary form of adult collection in California. In the Columbia River, Oregon permitees collect adults with gill nets. A surgical procedure is used to test for gamete maturity. If the eggs are mature, the female is transported to a culture facility where hormones are injected to induce ovulation. When the eggs are ripe they are surgically collected (Conte et al. 1988). After a recovery period, adults are tagged and returned to the wild. A permit system regulates the capture of adult fish and gamete collections in California and Oregon.

There have not been systematic evaluations of delayed mortality of wild brood fish. California does not report delayed mortality of adults from the gamete collection program. In 1989, California instituted a tagging program to monitor the brood fish; in October 1991 the first of these tagged fish was caught by an angler. Oregon reported the delayed mortality of two brood fish in 1988 and two in 1991.

Wild broodstock collections will probably not continue indefinitely. Six to 11 commercial facilities are developing hatchery broodstock. Most California growers use captive males for breeding. Some commercial growers in California collected eggs from domestic females for the first time in 1990. California anticipates that hatchery-reared brood fish will replace wild brood fish in the near future (D. Kohlhorst, CDFG, pers. commun.).

Although culture facilities can incubate and rear sturgeon, the industry is striving to refine techniques and increase its success. Nutrition, particularly for the larval stage, needs improvement. Initiation of feeding at the proper time and diet are critical for larval survival (Doroshov and Binkowski 1985). White sturgeon larvae use live foods more efficiently than dry or semi-moist feeds (Buddington and Doroshov 1984; Buddington and Christofferson 1985; Doroshov and Binkowski 1985; Dabrowski et al. 1987). Larvae fed a mix of live and semi-moist diets survived at a rate of 40-60% (Doroshov and Binkowski 1985). Larvae suffer higher mortalities on a dry diet than on live or semi-moist diets (Buddington and Doroshov 1984). Larvae fed only a semi-moist diet grow 40% slower than those on live diets (Buddington and Doroshov 1984). Dry diets were the least desirable.

Food designed specifically to optimize survival, health, and growth of white sturgeon is not available. Some diet composition data are available (Appendix D). Evaluations of sturgeon diets vary from studies of flesh composition, survival, and growth (Hung et al. 1987b; Stuart and Hung 1989). Flesh composition studies provide an index of growth and nutritive value. Flesh with high lipid, protein, and moisture indicates a rapidly growing fish. Comparison of flesh from both wild and hatchery sturgeon may provide insight into the quantity and quality of food in the wild. Hung et al. (1987a) performed proximate composition analyses of wild and hatchery-reared white sturgeon. The composition values for both groups did not vary significantly from each other, although body weight, carcass weight, and liver weight differed significantly between the groups. The differences in weight were attributed to optimal culture conditions available to hatchery fish.

A. HISTORY OF STOCKING EFFORTS

White sturgeon stocking programs are experimental and none of the Pacific states presently have on-line programs to maintain or enhance populations through hatchery propagation.

From 1980-1988, the CDFG required private sturgeon culture facilities to release hatchery-reared fry or fingerling (young-of-the-year) sturgeon into the wild as mitigation for the gametes they collected from wild fish. There were 6-13 permits issued each year for gamete collection. Each permittee could collect eggs from six females. The number and age of the young sturgeon released were at the discretion of the grower, within the confines of the permit (B. Hulbrock, CDFG, pers. commun.). These release programs were not evaluated. None of the planting programs required marked fish, so survival of hatchery-reared juvenile sturgeon in the wild, optimum planting size, and the influence of planting time and location are unknown.

A horizontally transmitted virus infecting the digestive tract caused mortality in 1984-1986 in California hatcheries (Hedrick et al. 1991). There are no recent reports of this virus and its presence did not affect the mitigation planting program.

Upon the outbreak of the white sturgeon iridovirus (WSIV) in 1988, the CDFG suspended the mitigation planting program. An increased understanding of this virus may help control its spread.

Despite California's suspension of the mitigation program, juvenile sturgeon carrying the WSIV may have been transported outside the state. California regulates the importation of live fish with a permit system, but not the exportation. Aquaculturists regularly ship juvenile sturgeon to several states in the United States as well as foreign countries. The receiving state is responsible for disease screening and transportation of potentially diseased fish within its boundaries.

Two Oregon companies collect wild broodstock from the Columbia River, including oversized fish. The operators must allow biologists to monitor broodstock collection efforts, spawning, and subsequent release of the spawning fish back to the river. Each permittee may collect eggs from six adult females. Collections remain below the total annual allowable 18-female collection limit since there have been only two permits (see Section III. A.).

To mitigate for the loss of natural egg production by broodstock collected from wild fish, Oregon has a fingerling replacement requirement. In the past, the ODFW required larval replacement fish, but now stipulates stocking replacement fish as 3-6 in (8-15 cm) fingerlings. The number and size required may vary annually; since 1988, the permits have required 1,000 fingerlings per female spawned. Through 1991 all fingerlings have been stocked in the Willamette River above Willamette Falls.

B. CURRENT CONSERVATION PROPAGATION PROGRAMS

Public Programs

Conservation propagation approaches vary in the region. Idaho's program is an experimental program, not a supplementation program, using state hatchery space and evaluations of marked releases. Oregon plants "replacement" fish, obtained through the gamete collection program, into the Willamette River above Willamette Falls, a natural barrier to sturgeon migration. Although the 1990 replacement fish were OTC marked, there are no ongoing evaluation programs for the small number of fish planted in Oregon. California "replacement" fish were put back into their natal river basin without evaluation programs. Washington has no public sturgeon propagation programs. British Columbia is cooperating with the IDFG and local tribes in planning the Kootenai River sturgeon enhancement program.

Idaho recently began experimental programs in both the Snake and Kootenai River basins. The IDFG instituted a gamete collection program in the Snake River. The juvenile sturgeon (12 in; 30 cm TL) were tagged with passive integrated transponder (PIT) tags and released into the middle Snake River in 1989; this represents the first tagged release of juvenile white sturgeon raised in a hatchery. Sturgeon were planted in two sections of the river: (1) in areas where recruitment already occurs between Bliss and C.J. Strike dams, at the rate of 16.1 fish/mile (10 fish/km); and (2) into an area where recruitment seems limited between Lower Salmon Falls and Bliss dams, at a rate of 161 fish/mile (100 fish/km). The IDFG plans to compare growth and survival of these fish.

The Kootenai River program began in 1990. Obtaining mature males and females simultaneously was difficult and prompted sperm preservation research. Of the 55,000 fertilized Kootenai River sturgeon eggs obtained in 1989, only 100 juveniles survived to 2 months of age. Egg mortality was high and deformities were common in the larvae that hatched. The IDFG, Kootenai Indian Tribe, and the Bonneville Power Administration are cooperatively developing a hatchery dedicated to sturgeon enhancement in the Kootenai River. The hatchery is now operating.

The ODFW has planted both hatchery and wild sturgeon in non-natal rivers as an experimental enhancement program. Oregon has planted both wild fish collected from the Columbia River (in the 1950s) and the mitigation fish from commercial hatcheries into the Willamette River, upstream from Willamette Falls. Wild juvenile sturgeon were collected in the Columbia River and held in hatchery ponds, but they experienced high mortality prior to release in the Umpqua River.

<u>Private Aquaculture</u>

California facilities incubate and rear sturgeon for commercial sale. Nearly 50 facilities register for sturgeon production each year, but only five or six consistently collect eggs and rear juvenile sturgeon for market. There are five commercial sturgeon facilities in California that each produce more than 10,000 lb (4,540 kg) annually. During 1989, total sturgeon production for all facilities was about 1 million lb (454,000 kg). Most of the flesh goes to the fresh fish market as 4.4-30.9 pound (2-14 kg) fish. A commercial facility produces fish of the following sizes for market.

3.3 lb (1.5 kg) fish in 18 months
5.1-7.1 lb (2.3-3.2 kg) fish in two years
11.9-14.1 lb (5.4-6.4 kg) fish in three years
20.1-30.0 lb (9.1-13.6 kg) fish in four years

Private aquaculture in California extended into Oregon in 1981 with the collection of wild broodstock from the Columbia River.

Oregon prohibits the sale of live juvenile sturgeon >6 in (>15 cm) TL without prior state approval. To grow the fish to market size, they are taken to facilities outside Oregon. The permitees must demonstrate that they are attempting to develop domestic broodstock for future use.

Washington permits grow-out facilities, but prohibits wild broodstock collection. In Washington, there are three private facilities that grow sturgeon they purchase from sources out-of-state.

Idaho prohibits the import of all sturgeon from any source. Idaho also prohibits wild brood collection in the state, unless it is done in cooperation with the state. Cooperative programs between the IDFG, the College of Southern Idaho, and the commercial fish industry provide private companies with eggs, larvae, or fingerlings needed for domestic broodstock development (T. Cochnauer, IDFG, pers. commun.). These policies effectively prohibit the use of wild broodstock by the commercial culture industry. The purpose of the policy is to preserve any population of white sturgeon with unique genetic material that might be present in Idaho rivers (Moore 1989).

The Canadian government prohibits the use of wild white sturgeon for commercial culture programs (Swiatkiewicz 1989). There is an interest in developing private aquaculture facilities in British Columbia, but none exist today (V. Swiatkiewicz, BCMEP, pers. commun.). There is one licensed aquaculture research facility at Malespina College, in Nanaimo, British Columbia, that maintains broodstock, incubates eggs, and rears white sturgeon (D. Lane, Malespina College, pers. commun.).

VII. ONGOING RESEARCH BY HABITAT MANAGEMENT UNIT

State and federal agencies are conducting complementary research projects, mainly in response to management needs. The results from these projects will provide fishery scientists with technical information needed to refine white sturgeon management in the Pacific states.

A. SACRAMENTO AND SAN JOAQUIN RIVERS

Most white sturgeon research in this region focuses on population management in the Sacramento-San Joaquin Estuary and on aquaculture.

Population Management

The CDFG Bay-Delta Division continues to study white sturgeon in the Sacramento-San Joaquin River system with support from Federal Aid to Sport Fish Restoration. Recent research focuses on monitoring population parameters as well as gaining new knowledge of population biology and dynamics. Contact: David Kohlhorst (209-466-4421) about the following projects.

A) Estimate abundance, mortality rates, and movement patterns of legal-sized fish using a tag-recapture program. This is part of the state's long-term sturgeon monitoring. The tagging occurs once (for 1-2 consecutive years) every 2-5 years. Recent tagging occurred in 1984, 1985, 1987, 1990, and 1991.

B) Estimate juvenile sturgeon abundance and year-class strength on a monthly basis using gill nets, otter trawls, and setlines. Concurrent monitoring of environmental parameters provides a basis to correlate environmental parameters with year-class strength.

D) Describe spawning habitats, spawning migrations, and specific sturgeon spawning sites in the Sacramento River.

CDFG regional biologists are attempting to re-establish the white sturgeon fishery in Shasta Lake. Managers bought, tagged, and stocked 400 juvenile white sturgeon (12-14 in; 30-35 cm) in Lake Shasta in May 1988. One tagged fish was recovered in the fish ladder at Red Bluff Dam (a low-head diversion impoundment downstream from Shasta Dam). The sturgeon was moving downstream in the ladder and was about 18 in (45 cm) long at the time of recovery, one year after planting. In addition, about 200 juvenile sturgeon were reared in floating cages for several months before release into the reservoir. Contact: Terry Healey (916-225-2300).

Aquaculture

UCD Aquaculture Program leads research on the culture of white sturgeon in the region. There are many ongoing research projects that will continue into the 1990s. Recent research by sponsoring departments is as follows.

Department of Animal Science (916-752-1250 or 916-752-x):

* Nutrition, development of a specific sturgeon diet - S. Hung (x=3580)
* Reproductive endocrinology - G. Moberg
* Domestic broodstock development and spawning - S. Doroshov (x=7603)
* Hatchery technology and sturgeon culture - F. Conte
* Population genetics - G. Gall & D. Bartley (x=1257, x=6028)
* Nutritional biochemistry - C. Calvert

Department of Veterinary Science (916-752-1360):

* Pathology and virology of white sturgeon - R. Hedrick (x=3411)

Department of Biochemistry (916-752-3611):

* Molecular biology of sturgeon - D. Carlson

Department of Fish and Wildlife Biology (916-752-6586 or 916-752-x):

* Environmental physiology of sturgeon - J. Cech (x=3103)
* Age, size, and population structure - L. Botsford (x=6169)

Private aquaculture spawned hatchery-reared broodstock in at least two facilities in 1990.

CDFG pathologists are actively investigating the iridovirus disease, which appeared in the late 1980s at California white sturgeon aquaculture facilities. Contact: Bill Wingfield (916-355-0811).

B. COLUMBIA RIVER DOWNSTREAM FROM BONNEVILLE DAM

White sturgeon research in the lower Columbia River is primarily a cooperative effort between states and with temporary funding from federal agencies. The WDF and ODFW monitor sturgeon within their harvest management programs. The WDF and ODFW continue a long-term project (begun in the mid 1960s) that monitors white sturgeon, incidental to salmon research (J. DeVore, WDF, pers. commun.). In 1983, WDF began a project through the Federal Aid to Fish Restoration (Dingell-Johnson) Program, which continues today (J. DeVore, WDF, pers. commun.). The ODFW also receives Sport Fish

* Gather biological data from recreationally caught salmonids, sturgeon, and shad.

Bonneville Power Administration-funded research is a cooperative effort between the WDF and the National Marine Fisheries Service. The research topics were derived from a basinwide work plan designed in 1985 (Fickeisen 1985a). Contact: John DeVore (WDF) 206-576-6073 or George McCabe (NMFS) 503-861-1818.

* Describe the early life history of white sturgeon in the Columbia River downstream from Bonneville Dam.

* Determine the habitat requirements for spawning and rearing of sturgeon in the Columbia River downstream from Bonneville Dam, including their invertebrate food supply.

C. MAINSTEM COLUMBIA RIVER FROM BONNEVILLE DAM TO CHIEF JOSEPH DAM AND THE LOWER SNAKE RIVER TO LOWER GRANITE DAM

The Bonneville Power Administration funds most of the white sturgeon research between Bonneville and McNary dams as a cooperative effort between the ODFW, WDF, and the USFWS. These projects began in 1986. Above McNary Dam, other state and federal funds (Dingell-Johnson) are used to sample recreational fisheries. Contact: Anthony Nigro (ODFW) 503-657-2038, Lance Beckman (USFWS) 509-538-2299, or John DeVore (WDF) 206-696-6261 for information about the multi-year project goals:

* Develop a standardized method of estimating potential production of white sturgeon in the reservoirs between Bonneville and McNary dams.

* Monitor recreational fishing as part of a study entitled "Recreational Fishery Monitoring below Priest Rapids Dam."

* Develop yield curves to compare productivity of impounded populations to that of the "control" population below Bonneville Dam to quantify the impacts of hydropower upon sturgeon populations.

* Describe the maturation cycle and spawning periodicity of sturgeon living between Bonneville and McNary dams.

* Describe the population dynamics of each white sturgeon population with estimates of total annual mortality, exploitation, and age and growth.

* Test validity of aging techniques with a secondary mark (in cooperation with the lower river research effort).

* Describe spawning and early life (12-31 in; 30-79 cm FL) habitat use of white sturgeon in the three pools. If possible, develop instream flow incremental methodology-type habitat use curves.

* Compare mark and tag retention, and the impact on survival.

* Determine limiting factors in sturgeon potential productivity.

* Recommend enhancement/mitigation measures for "hydropower impacted" sturgeon populations.

Batelle Northwest is the only organization conducting sturgeon research between McNary and Chief Joseph dams. Batelle Northwest is assessing and comparing the radionuclide burden in white sturgeon throughout the Columbia River Basin. Contact: Dennis Dauble (509-376-3631).

Beak Consultants recently evaluated the dioxin concentrations in white sturgeon tissues. The results are not public at this time. Contact: Doug Morrison (Northwest Pulp and Paper Mills) 206-455-1323.

The Oregon Department of Environmental Quality plans an evaluation of toxins in fish flesh in the Columbia River Basin. Sturgeon are a species of consideration, but are not yet included in the evaluation. Contact: Krystina Wolniakowski (503-229-5300).

The Environmental Protection Agency is conducting a basinwide dioxin evaluation. Contact: Bruce Kleland (206-553-2600).

D. COLUMBIA RIVER BASIN UPSTREAM FROM CHIEF JOSEPH DAM

Lake Roosevelt

University of Idaho personnel are radio-tracking white sturgeon in the Lake Roosevelt-Columbia River complex. In addition, they are continuing to evaluate the genetic composition of the population and comparing it to other populations. Contact: Ann Setter (208-885-5830).

The Washington Department of Ecology is examining the bio-accumulation and attenuation of toxins, including mercury and dioxins, in white sturgeon and other fish species in Lake Roosevelt and Lake Rufus Woods. The WDE recognized the need for research when Canadian agencies recommended to anglers that they should not eat whitefish caught in the Columbia River downstream from Castlegar. Contact: Art Johnson (206-586-6828).

Kootenai River Basin

The Bonneville Power Administration is funding a cooperative study between the IDFG and the Kootenai Indian Tribe to develop conservation hatchery facilities for incubating and rearing white sturgeon. The agency also plans an evaluation of the contribution of hatchery fingerlings to the population. Contact: Tim Cochnauer (208-743-6502), Kim Apperson (208-267-2714), or Jay Hammond (604-354-6344).

The BPA and IDFG white sturgeon research in the Kootenai River Basin focuses on:

* Defining the population(s) of white sturgeon in the Kootenai River Basin and determining if sturgeon in Idaho, Montana, and British Columbia represent a single or several discrete populations.

* Assessing reproductive potential of the population.

* Obtaining empirical data for instream flow incremental methodology habitat use curves for various life stages.

* Determining if hydroelectric projects influence white sturgeon production by altering flow regimes and habitats.

The IDFG and University of Idaho are attempting to cryo-preserve the sperm of white sturgeon to ensure sperm availability when gravid females are obtained. Contact: Joe Cloud (208-885-6388).

E. MAINSTEM SNAKE RIVER UPSTREAM FROM LOWER GRANITE DAM

Artificial Propagation for Conservation

The IDFG is evaluating survival and relative contribution of hatchery-reared fingerlings to the sturgeon populations in the Snake River between Lower Salmon Falls and Bliss dams. The IDFG marked all 1989 and 1990 releases with PIT tags. Contact: Virgil Moore (208-334-3791).

The University of Idaho is sampling sturgeon in Lower Granite Pool. Contact: Dave Bennett or Ken Leptic (208-885-6336).

Tagging Studies in Idaho

The IDFG is evaluating the practicality of using visual implant (VI) tags in sturgeon. Preliminary results suggest the skin of sturgeon does not allow visibility of the VI tag. Contact: Virgil Moore (208-334-3791).

The IDFG is also re-examining delayed mortality associated with pectoral fin clips as seen in California. Contact: Virgil Moore (208-334-3791).

Tacoma City Light contracted to have a few white sturgeon radio-tagged in the Snake River between Bliss and C.J. Strike dams. The data from this investigation are unpublished. Contact: Garth Jackson or Gary Johnson, Tacoma City Light (206-593-8318).

F. FRASER RIVER

British Columbia Ministry of Environment and Parks. Contact: Vic Swaitkiewkz (604-584-8822):

* Evaluation of the bio-accumulation of pesticides and heavy metals in several species of fish, including white sturgeon, in the Fraser River downstream from Hells Gate.
* Canadian biologists are testing OTC techniques for age validation experiments.
* Radio tracking of fish in the lower Fraser River (on contract to a consultant).

Simon Fraser University continues the examination of white sturgeon genetics to describe the potential interchange between populations throughout the Pacific states. Contact: James Brown (604-291-3540).

Malespina College. Contact: David Lane (604-758-6651):

* Compiling sturgeon harvest information for the Fraser River system.
* Developing a captive Fraser River broodstock.
* Conducting sturgeon behavior evaluations.

G. PACIFIC COAST AND COASTAL RIVERS

There are no on-going white sturgeon research projects in Puget Sound, along the Washington coast, Grays Harbor, Willapa Bay, or the California coast. Incidental information may be obtained by the WDF from out-of-basin recoveries of Columbia River tagged sturgeon. Contact: John DeVore (206-696-6261).

The ODFW has recently implemented a sturgeon tagging program using volunteer anglers and taggers in the Oregon estuaries. Contact: Don Swartz (503-657-2031).

Oregon State University tagged white sturgeon in Yaquina Bay, 1980-1985, but the data are unpublished. Contact: Howard Horton (503-737-2228).

The ODFW is compiling a 20-year data set including incidental white sturgeon data in the Rogue River Basin. Contact: Al Smith (503-229-5000) or Tom Satterthwaite (503-474-3145).

VIII. WHITE STURGEON MANAGEMENT FRAMEWORK PLAN GOALS FOR THE FUTURE

1) Establish and/or maintain viable white sturgeon populations throughout the historic range.

2) Sustain optimum and/or maximum benefit for diverse consumptive and non-consumptive uses.

3) Protect and enhance critical habitat in each management unit.

4) Promote public awareness of the white sturgeon resource.

5) Protect the genetic integrity of local populations of white sturgeon.

Definitions for these goals are as follows.

A population consists of either:

A) Landlocked individuals using a discrete region of a river that may be bounded by dams or other barriers; or

B) Individuals in a particular river with access to the ocean and other river basins, but defined by the river of freshwater origin.

Where rivers provide a fishery with migratory individuals from another river basin, we use the term "transient population." A viable, healthy population is one that can sustain fishing opportunity, and preferably, harvest opportunities for the public. Webster's dictionary defines viable as capable of existence and development as an independent unit.

A. OBJECTIVES

* Define a viable, healthy naturally reproducing population in measurable terms, such as the estimated minimum abundance by age class or proportional representation of age structure.

* Identify viable populations and their genetic characteristics.

* Define optimum sustained yield (OSY) or maximum sustained yield (MSY) in terms of fish weight, fish numbers, or catch rate for each management unit.

* Define the range of exploitation that may provide OSY or MSY for naturally sustained populations. If consumptive harvest is not feasible, define the range of acceptable fishing mortality rates for catch and release regulations. Modify regulations appropriately for consumptive and non-consumptive fisheries.

* Identify "critical" habitats for each life history stage.

B. POTENTIAL PACIFIC STATES MARINE FISHERIES COMMISSION FUNCTIONS FACILITATING STURGEON MANAGEMENT

* Explore the feasibility of coordinating the development of population modeling services for member states.

* Explore the feasibility of assisting in the development of a regional sturgeon information and retrieval service that continually updates both biological and socio-economic data.

* Explore the feasibility of providing an ongoing forum for ensuring that research projects address issues in a logical sequence, each providing a refinement to regional knowledge of population and habitat management.

* Explore the feasibility of coordinating the development of a regional evaluation and monitoring of the economic value of the fishery.

IX. ADDITIONAL RESEARCH NEEDS BY MANAGEMENT UNIT

Some questions will remain unanswered, despite the volume of research already under way. The White Sturgeon Planning Committee recommends a coordinated peer review system for research planning and technical review of analyses. Most of the research to date has not been subject to the rigors of peer review.

It is not the purpose of this document to reiterate research priorities of the states. The WSPC reviewed and prioritized the proposed research. All management units will benefit from each project. However, the planning committee agrees that the management unit with the greatest need for a particular area of knowledge should conduct the research, if funds are available. Therefore, the following list associates most research needs with a particular management unit.

A. SACRAMENTO-SAN JOAQUIN RIVER SYSTEM

Priority 1 — Develop a (or refine the present) population model to evaluate the potential for angling regulation changes to maintain the fishery.

Priority 2 — Refine current knowledge of spawning sites in the mainstem of the Sacramento River and the subsequent distribution of larval and juvenile sturgeon in the river upstream from the estuary.

Priority 3 — Implement a study to confirm the apparent relationship between year-class strength and spring and summer flows by refining the measure of year-class strength and determining the mechanisms for this relationship.

Priority 4 — Develop a genetic profile of white sturgeon from the Sacramento-San Joaquin Estuary.

B. COLUMBIA RIVER BASIN

Fickeisen (1985a) presents a list of research needs related to hydropower development impacts for white sturgeon in the Columbia River Basin. This White Sturgeon Management Framework Plan adopts the research priority matrix set forth in Fickeisen (1985a) and reproduced here as Appendix E. The following priority listing is derived from the Fickeisen (1985a) plan.

General Needs

* Identify genetic stocks and the extent of mixing among and within the Columbia, Fraser, and Sacramento rivers and coastal areas. Results of current studies using electrophoresis and mtDNA are incomplete. Fundamental questions concerning the existence of fluvial and anadromous stocks and the adequacy of present sampling methods for detecting genetic differences observed among Columbia River reservoir populations remain unanswered.

* Determine effects of toxic pollutants (organochlorines, dioxins, and trace metals) on sturgeon production and human health.

* Develop a technique for estimating sex and maturity from blood chemistry to facilitate estimation of reproductive potential.

* Develop a tag or mark with long-term retention and recognition qualities.

* Estimate effects of substrate composition and infiltration on egg incubation success.

Downstream from Bonneville Dam

Priorities identified by Fickeisen (1985a)

* Estimate broodstock abundance.

* Estimate carrying capacity.

* Assess population abundance and potential for enhancement in the Willamette River above Willamette Falls.

* Refine estimates of exploitation and natural mortality rates.

* Define stock-recruitment relationships.

* Quantify relationship between reproduction, flow, and dam operations.

* Describe food habits of all life stages.

* Determine effects of dredging and other human disturbance on the food supply for juveniles.

* Quantify use of the ocean and other coastal waters.

* Describe physical habitat use by adults and subadults.

* Quantify habitat available for juvenile through adult fish.

Additional priorities identified by the White Sturgeon Planning Committee

* Determine optimum sustainable levels of harvest and the impact of alternative regulations.

* Determine user preference for sustained yield in terms of size or numbers.

<u>Bonneville Dam to McNary Dam</u>

Priorities identified by Fickeisen (1985a)

* Estimate carrying capacity.

* Define stock-recruitment relationships.

* Estimate catch and effort in ceremonial and subsistence fisheries.

* Estimate incidental mortality of sublegal and oversized fish in fisheries.

* Quantify relationship among reproduction, flow, and dam operations.

* Investigate the effects of predation on egg and larval survival.

* Describe food habits of all life stages.

* Describe physical habitat use by adults and subadults.

* Describe physical habitat use by larvae and post-larvae.

Additional priorities identified by the White Sturgeon Planning Committee

* Evaluatė mitigative measures for dam construction and operation recommended in ongoing studies.

* Collect and analyze tissue samples to determine agricultural and industrial toxin levels, and evaluate effects on gamete viability.

McNary Dam to Chief Joseph and Ice Harbor Dams

Priorities identified by Fickeisen (1985a)

* Estimate numbers of subadult and adult fish.
* Estimate age composition, growth, and survival.
* Identify spawning period and estimate age at maturity, spawning periodicity, sex ratio, fecundity, and reproductive potential.
* Identify factors limiting reproduction and recruitment.
* Describe food habits of all life stages.
* Determine the extent to which migration has been affected by dam construction and operation.
* Define physical habitat requirements for completion of all life history stages.
* Quantify physical habitat available to all life history stages.

Additional priorities identified by the White Sturgeon Planning Committee

* Determine optimum sustainable levels of harvest.

Columbia River Upstream from Chief Joseph Dam

Priorities identified by Fickeisen (1985a)

* Estimate numbers of subadult and adult fish.
* Estimate age composition, growth, and survival.
* Identify spawning period and estimate age at maturity, spawning periodicity, sex ratio, fecundity, and reproductive potential.
* Determine effects of water chemistry (including toxicants) on egg viability, fertilization, and incubation.
* Identify factors limiting recruitment (see above also).
* Describe food habits of all life stages.

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* Determine the extent to which migration has been affected by dam construction and operation.

* Define physical habitat requirements for completion of all life history stages.

* Quantify physical habitat available to all life history stages.

Additional priorities identified by the White Sturgeon Planning Committee

* Determine optimum sustainable levels of harvest.

Prioritized Kootenai River Research

<u>Priority 1</u> Determine the relationship between water quality (including toxicants) and egg viability, fertilization, and incubation.

<u>Priority 2</u> Determine the tolerance levels of larval and juvenile white sturgeon to common toxins.

<u>Priority 3</u> Define critical habitats.

<u>Priority 4</u> Determine genetic profiles of viable populations.

<u>Priority 5</u> Describe food habits of all life stages.

<u>Mainstem Snake River Between Ice Harbor and Lower Granite Dams</u>

Priorities identified by Fickeisen (1985a)

* Estimate numbers of subadult and adult fish.

* Estimate age composition, growth, and survival.

* Identify spawning period and estimate age at maturity, spawning periodicity, sex ratio, fecundity, and reproductive potential.

* Identify factors limiting recruitment.

* Describe food habits of all life stages.

* Determine the extent to which migration has been affected by dam construction and operation.

* Define physical habitat requirements for completion of all life history stages.

* Quantify physical habitat available to all life history stages.

Additional priorities identified by the White Sturgeon Planning Committee

* Determine optimum sustainable levels of harvest.

* Investigate toxin accumulation in white sturgeon flesh in the Columbia River Basin. The WSPC believes that toxin accumulation in white sturgeon flesh should be investigated in the Columbia River Basin with respect to its influence on human health. This issue was not directly related to hydropower impacts and therefore not relevant to the participants in the process recorded by Fickeisen (1985a).

<u>Mainstem Snake River Upstream from Lower Granite Dam</u>

* Update estimates of subadult and adult numbers.

* Update estimates of age composition, growth, and survival.

* Identify spawning period and estimate age at maturity, spawning periodicity, sex ratio, fecundity, and reproductive potential.

* Identify factors limiting recruitment.

* Describe food habits of all life stages.

* Define physical habitat requirements for completion of all life history stages including water quality and quantity requirements.

* Quantify physical habitat available to all life history stages.

* Determine the extent to which migration has been affected by dam construction and operation.

Prioritized Research for the Mainstem Snake River Upstream from Lower Granite Dam

<u>Priority 1</u> Develop a statewide white sturgeon management plan and a coordinated plan between Idaho and Oregon and between Idaho and Washington for waters administered jointly.

<u>Priority 2</u> Define the water quality and quantity requirements of white sturgeon.

Priority 3 Conduct a genetic inventory of sturgeon populations.

Priority 4 Determine the toxicity threshold of white sturgeon for a variety of toxins.

Priority 5 Update population parameters for the Hells Canyon Dam to Lower Granite Dam section and the Bliss Dam to C.J. Strike section of the Snake River.

Priority 6 Develop guidelines for sturgeon supplementation in the event it becomes a feasible management alternative.

Priority 7 Evaluate the impact of catch-and-release fishing on vitellogenesis of white sturgeon, particularly during the spring.

Priority 8 Determine what sturgeon anglers want.

Priority 9 Develop techniques and protocol for cryopreservation of sperm.

C. FRASER RIVER

* Determine if toxins bioaccumulate in the flesh of white sturgeon, thus creating a health hazard for anglers and others eating wild fish.

* Describe sturgeon distribution in the Fraser River Basin and identify viable populations. Describe the life history of each population.

* Estimate population abundance, sustainable exploitation, and actual exploitation for each viable population.

* Determine if all British Columbia sturgeon originate in the Fraser River system and, if not, what proportion of the population originates elsewhere.

D. PACIFIC COAST AND COASTAL RIVERS

* Describe the economic value of white sturgeon to coastal communities.

* Determine the origin of coastal populations, and determine if they are viable.

* Describe the CPUE and delayed mortality of sublegal and oversized fish for each major gear type potentially used in marine and estuary fisheries.

X. RECOMMENDATIONS TO THE REGION

The Pacific States Marine Fisheries Commission recommends to the management agencies the following activities, which would promote scholarly research, promote communication of technical data, streamline research, and provide a broader basis for white sturgeon management activities in the Pacific states.

A) Develop regional scientific standards for sturgeon sampling, handling, data presentation, and modeling.

B) Develop estimates of sustainable fishing opportunity and yield based on a central modeling data base.

C) Develop a management plan for each population including enhancement and regulation options to achieve sustainable fishing opportunity. As a component of each population management plan, a program designed to protect, develop, and enhance critical habitat should be included.

D) Determine contaminants (toxins) potentially impacting white sturgeon reproductive capacity.

E) Develop comprehensive sturgeon culture and nutrition technology.

F) Provide a forum for peer review of study plans to provide comparable data, improve communications, and minimize questions of technical validity.

G) Provide a centralized annotation and retrieval service.

H) Provide a centralized tag recovery data base to assist in the understanding of marine and inland movement of white sturgeon.

I) Provide a central data base documenting bio-accumulation of toxins in white sturgeon that are significant hazards to human health.

J) Provide a central data base identifying the genetic characteristics of each population as the data become available.

K) Support research to identify critical habitat for each white sturgeon life history stage.

L) Develop a plan to promote a scientifically acceptable method of recording white sturgeon recreational angling data for Oregon, Washington, and California, including ocean waters and Native American subsistence fisheries.

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APPENDIX A
Biological Data

Table A1. Meristic characteristics used to separate young-of-the-year (YOY) white and green sturgeon (adapted from Schreiber 1959, 1960).

Meristic characteristic	YOY white sturgeon	YOY green sturgeon
Ratio distance from snout to barbels[1] / distance from barbels to mouth	0.73-1.31	1.57-2.86
Number of dorsal fin rays[2] (all rays regardless of size)	42-53	35-40
Number of lateral scutes (counted until they first turn upward at base of the caudal fin)	36-46	23-30
Number of gill rakers on the first gill arch	23-30	15-19

[1] Ratio measurement from barbels to the edge of the ridge around the mouth, not to the inner edge of the lip.

[2] Some taxonomists also use anal fin ray counts to identify small white sturgeon from green sturgeon, but it is not a diagnostic character. Schreiber (1959, 1960) found similar numbers of anal fin rays for these two species.

Table A2. White sturgeon passage at Bonneville Dam, 1938-1990 (compiled from U.S. Army Corps of Engineers annual fish passage reports).

Year	Ladder[1]	Fish locks[2]	Total passed
1938			44
39			352
1940			2
41			28
42			547
43			0
44			0
1945			1
46			832
47			78
48	2	79	81
49	3	1	4
1950	27	1,499	1,526
51	22	1,039	1,061
52	11	10	21
53	6	7	13
54	1	0	1
1955	3	3	6
56	5	39	44
57	0		0
58	2		2
59	0		0
1960	0		0
61	0		0
62	1		1
63	6		6
64	3		3
65	1		1
66	1		1
67	4		4
68	3		3
69	3		3

Table A2 (cont.). White sturgeon passage at Bonneville Dam, 1938-1990 (compiled from U.S. Army Corps of Engineers annual fish passage reports).

Year	Ladder[1]	Fish locks[2]	Total passed
1970	0		0
71	0		0
72	0		0
73	0		0
74	43		43
1975	8		8
76	6		6
77	0		0
78	31		31
79	82		82
1980	33		33
81	77		77
82	73		73
83	62		62
84	0		0
1985	33		33
86	41		41
87	20		20
88	24		24
89	60		60
1990	47		47

[1] Sturgeon counted in ladder passing upstream and downstream combined (records don't say which way).

[2] Locks not in use since 1956; fish passed upstream.

Table A3. The timing of spawning and water temperatures at spawning throughout the range of white sturgeon.

River basin	Time of spawning Range	Time of spawning Peak	Temperature (C) Range	Temperature (C) Peak
Culture Situations				
Sacramento[a]	--	--	13-17	15
Field Situations				
Sacramento River[b]	Feb - May	Mar - Apr	8-18	14
Columbia River Downstream from Bonneville Dam[c]	Apr - June	--	10-16	--
Columbia River Downstream from Bonneville Dam[d]	Apr - July	May	9-17	10-15
Columbia River Upstream from Bonneville Dam[e]	May - July	June	12-21	13-19
Kootenai River[f]				
Fraser River[g]	May - June	--	9-17	--

[a] Conte et al. 1988
[b] Kohlhorst 1976
[c] McCabe et al. 1989; McCabe and Hinton 1990
[d] Kreitman and LaVoy 1989; Galbreath 1979, 1985; Bajkov 1949
[e] Parsley et al. 1989; Duke et al. 1990.
[f] Scott and Crossman 1973

Table A4. Food habits of wild white sturgeon, by size class, for semi-anadromous and landlocked populations and pertinent laboratory studies (lab).

Fish size	Citation	Diet
Fry 2-8 cm		
(lab)		
	Brannon et al. 1987	similar size fry
Fish less than 20 cm (TL)		
(semi-anadromous)		
	Brannon et al. 1987 (lab)	similar size fry
	Muir et al. 1988	Corophium salmonis
	Schreiber 1960	Corophium spinicorne Neomysis mercedis Tendipedidae adult Diptera
	Turner and Kelley 1966	Neomysis mercedis Corophium spp. polychaetes tendipedids Alosa sapidissima
Fish 20-40 cm (TL)		
(semi-anadromous)		
	Muir et al. 1988	Corophium salmonis Neomysis mercedis
	Turner and Kelley 1966	Neomysis mercedis Corophium spp. polychaetes tendipedids Alosa sapidissima
	Radtke 1966	Corophium spp. Neomysis spp.

Table A4 (cont.). Food habits of wild white sturgeon, by size class, for semi-anadromous and landlocked populations and pertinent laboratory studies (lab).

Fish size	Citation	Diet
Fish 20-40 cm (TL) (cont.).		
	McCabe and Hinton 1989	Corophium salmonis Corophium spinicorne eulachon eggs
(lab)	Brannon et al. 1987	fry (live or dead) eggs buried in gravel (dead)
Fish 40-60 cm (TL)		
(semi-anadromous)		
	Muir et al. 1988	Corophium salmonis Neomysis mercedis Crangon franciscorum Saduria entomon
	Radtke 1966	Corophium spp. Neomysis spp.
	McCabe et al. 1989	Corophium salmonis Corophium spinicorne eulachon eggs Corbicula manilensis
(landlocked)	Duke et al. 1990	Corophium salmonis Corophium spinicorne Ramellogammarus oregonensis Neomysis spp. Corbicula spp. misc. Cladocera and copepods
(lab)	Brannon et al. 1987	fry (live or dead) eggs buried in gravel (dead)

Table A4 (cont.). Food habits of wild white sturgeon, by size class, for semi-anadromous and landlocked populations and pertinent laboratory studies (lab).

Fish size	Citation	Diet
<u>Fish 60-80 cm, or less than 80 cm TL</u>		
(semi-anadromous fish)		
	Muir et al. 1988	<u>Corophium salmonis</u>
	Turner and Kelley 1966[1]	<u>Neomysis</u> spp. (used all year) <u>Corophium</u> spp. used winter-summer <u>Pleomon macrodactylus</u> used in fall <u>Corbicula fluminea</u> used in fall <u>Macoma</u> spp. <u>Synidotea laticauda</u> <u>Crangon franciscorum</u>
	Muir et al. 1988	<u>Crangon franciscorum</u>
	Muir et al. 1988	<u>Engraulis mordax</u> (seasonal) <u>Thaleichthys pacificus</u> (seasonal)
	Semakula and Larkin 1968	eulachons (primarily already dead) sculpins sticklebacks lamprey other young sturgeon chironomids crayfish stonefly larvae mayfly larvae mysids <u>Chaoborus</u> spp. larvae <u>Daphnia</u>
(landlocked fish)		
	Coon et al. 1977	fly larvae

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Table A4 (cont.). Food habits of wild white sturgeon, by size class, for semi-anadromous and landlocked populations and pertinent laboratory studies (lab).

Fish size	Citation	Diet
Fish 60-80 cm, or less than 80 cm TL (cont.)		
	Cochnauer 1981, 1983	chironomids
		clams
		snails
		crayfish
		caddisflies
		amphipod shrimp
		misc. other genera of aquatic insects
		fish
	Duke et al. 1990	*Corophium* spp.
		Pacificatus spp.
		Corbicula manelensis
		Ramellogammarus oregonensis
		Neomysis spp.
		oligochaetes
Fish more than 80 cm TL		
(semi-anadromous)		
	Semakula and Larkin 1968	eulachons (primarily already dead)
		sculpins
		sticklebacks
		lamprey
		other young sturgeon
		chironomids
		crayfish
		stonefly larvae
		mayfly larvae
		mysids
		Chaoborus sp. larvae
		Daphnia
	Muir et al. 1988	anchovies

Table A4 (cont.). Food habits of wild white sturgeon, by size class, for semi-anadromous and landlocked populations and pertinent laboratory studies (lab).

Fish size	Citation	Diet
Fish more than 80 cm TL (cont.)		
	McKechnie and Fenner 1971	*Crago* spp.
		Palaemon macrodactylus
		Neomysis spp.
		isopods and amphipods
		barnacles
		Rhithropanopeus harrisii (crab)
		Cancer magister
		clams- *Gema* spp., *Macoma* spp., *Tapes semidecussata*
		mussels- *Mytilus* spp.
		snails
		Morone saxatilis
		Platichthys stellatus
		Engraulis mordax
		Clupea harengus pallasi
		Porichthys notatus
		Leptocottus armatus
		misc. polychaetes and nematodes
	Bajkov 1949	mollusks
		crustaceans
		insect larvae
		other benthic invertebrates
		fish
	Galbreath 1985	eulachon - spring
		anchovies - fall
(landlocked)		
	Coon et al. 1977	*Corbicula* spp.
		crayfish
		caddisflies
		dipteran larvae
		snails

Table A4 (cont.). Food habits of wild white sturgeon, by size class, for semi-anadromous and landlocked populations and pertinent laboratory studies (lab).

Fish size	Citation	Diet
Fish more than 80 cm TL (cont.)		
	Cochnauer 1981, 1983	chironomids clams snails crayfish caddisflies amphipod shrimp misc. other genera of benthic insects
	Partridge 1980,1981,1983	chironomids clams snails fish mayflies stoneflies annelids plant matter

[1] Larger juveniles are fish 40-102 cm.

Table A5a. Estimated length at age (cm TL or cm FL as labeled beside the letter) for white sturgeon from various regions for individuals 1-12 years of age. All references are given on the last page of the length-at-age tables.

	Age											
Region	1	2	3	4	5	6	7	8	9	10	11	12
California												
a, TL)	18	23	28	32	35	38	41	44	46	48	50	57
b, TL)	45	53	61	69	77	84	91	98	104	110	116	122
c, TL)	43	53	62	71	79	87	95	102	108	115	121	127
Columbia, Downstream from Bonneville												
d,)	18-23											
e, FL)									102			123
f, FL)	20	30	40	50	60	70	80	90	98	105	113	120
g, FL)	24	32	38	41	42	44	48					
h, TL)	36	40	46	58	63	71	80	85	97	106	113	127
Canada/Fraser												
i, FL)	12-37											
j, FL)	23	31	36	43	50	55	61	66	72	78	86	89
Columbia, Upstream from Bonneville												
John Day Pool												
o, FL)	–	34	39	45	47	60	74	78	82	93	107	103
The Dalles Pool												
g, FL)	–	37	41	47	56	63	68					
o, FL)	27	36	42	45	52	61	62	79	83	88	97	100
Bonneville Pool												
g, FL)	–	38	44	47	51	55	59					
o, FL)	–	36	38	46	49	56	66	65	67	80	86	91
Idaho												
Kootenai												
k, FL)	–	–	–	54	–	64	70	76	79	82	86	96
Snake/Hells Canyon												
[illegible], TL)	–	–	52	59	60	62	65	68	71	72	72	74
[illegible], TL)	13	34	42	47	55	63	65	68	70	71	72	77
[illegible], TL)	–	–	53	59	60	63	65	68	70	72	72	77

Table A5a (cont.). Estimated length at age (cm TL or cm FL as labeled beside the letter) for white sturgeon from various regions for individuals 1-12 years of age. All references are given on the last page of the length-at-age tables.

Region	Age 1	2	3	4	5	6	7	8	9	10	11	12
Idaho (cont.)												
Snake/Walters Ferry to Swan Falls												
(m, TL)	--	--	--	--	71							
Snake/Swan Falls to CJ Strike												
(m, TL)	--	--	--	--	73	84	83	81	94	--	--	--
Snake/Middle												
(n, TL)	--	49	52	58	58	61	63	64	66	68	69	72
Snake/Upper Middle Snake												
(m, TL)	--	53	60	64	69	74	78	90	97	104	112	127
Snake/Bliss to Lower Salmon Falls												
(m, TL)	--	--	--	86	83	--	--	159	129	--	--	--
Snake/Upper Salmon Falls to Shoshone Falls												
(m, TL)	--	--	--	118	102	--	138	--	150	--	160	--

able A5b. Estimated length at age (cm; see previous page for FL or TL) for white sturgeon from various regions for individuals 13-23 years of age. All references can be found on the last page of the length-at-age tables.

	Age										
egion	13	14	15	16	17	18	19	20	21	22	23
alifornia											
'a)	55	57	59	61	64	66	68	71	73	76	78
)	128	133	138	143	147	152	156	160	164	168	172
)	132	137	142	146	151	155	159	163	166	170	173
olumbia, Downstream from Bonneville											
d)											
e)											183
	128	136	143	150	158	166	174	181	189	—	183
/l)	129	137	144	153	159	162	168	167	172	167	170
nada/Fraser											
i)	94	99	104	109	114	118	122	127	131	135	140
olumbia, Upstream from Bonneville											
	John Day Pool										
	110	118	120	121	123	129	135	138	148	163	
	The Dalles Pool										
	108	113	118	120	126	131	136	140	137	154	152
	Bonneville Pool										
	99	101	107	107	108	114	115	118	129	123	136
laho											
	Kootenai										
:)	92	–	105	113	108	113	116	121	133	136	149
	Snake/Hells Canyon										
)	78	83	84	88	92	101	113	136	128	165	—
	79	82	83	86	90	105	111	129	132	150	155
	79	82	83	86	90	105	111	129	132	162	–

Table A5b (cont.). Estimated length at age (cm; see previous page for FL or TL) for white sturgeon from various regions for individuals 13-23 years of age. All references can be found on the last page of the length-at-age tables.

Region	Age 13	14	15	16	17	18	19	20	21	22	23
Idaho (cont.)											
Snake/Walters Ferry to Swan Falls											
(m)											
Snake/Swan Falls to CJ Strike											
(m)											
Snake/Middle											
(n)	75	78	78	94	104	97	135	—	152	—	—
Snake/Upper Middle Snake											
(m)	133	134	161	172	164	170	—	201	193	229	—

Table A5c. Estimated length at age (cm; see first page of length at age information) for white sturgeon from various regions for individuals 24-34 years of age. All references can be found on the next page.

	Age										
Region	24	25	26	27	28	29	30	31	32	33	34
California											
(a)	80	83	85	88	90	93	95				
(b)	175	179	182	185	188	191	194				
(c)	176	178	181	184	186	188	191				
Columbia, Downstream from Bonneville											
(d)											
(e)											
(f)											
(h/l)	182	177	192	182	181	232	208	292			
Canada/Fraser											
(i)	144	148	152	156	160	163	166	169	173	176	179
(k)											
Columbia, Upstream from Bonneville											
John Day Pool											
(o)	159	168	184	--	220	190					
The Dalles Pool											
(o)	155	160	175	180	169	190					
Bonneville Pool											
(o)	125	148	156	154	161	175					
Idaho											
Kootenai											
(k)	157	159	158	159	181	176	192	172	186	170	201

Table A5c (cont.). Estimated length at age (cm; see first page of length at age information) for white sturgeon from various regions for individuals 24-34 years of age. All references can be found on the next page.

	Age										
Region	24	25	26	27	28	29	30	31	32	33	34
Idaho (cont.)											
	Snake/Hells Canyon										
(l)	178	171	162	178	154	—	195	243			
	160	165	170	177	180	190	195				
	165	156	162	178	154	—	195	—	—	214	—
	Snake/Walters Ferry to Swan Falls										
(m)											
	Snake/Swan Falls to CJ Strike										
(m)											
	Snake/Middle										
(n)	194	169	–	–	196	215	202	—	218	226	218

References for the length at age data in Tables A5a, A5b, and A5c:

(a) Pycha 1956
(b) Kohlhorst 1980 $l_t = 261.2\ [1 - e^{-0.04027(t+3.638)}]$
(c) Brennan and Cailliet 1989 $l_t = 230.59\ [1 - e^{-0.0533(t+2.9176)}]$
(d) Bajkov 1949
(e) LaVoy et al. 1989
(f) Kreitman and LaVoy 1989
(g) Parsley et al. 1989
(h) Hess 1984; e(1947-53),l(1980-83)
(i) Scott and Crossman 1973
(j) Semakula 1963
(k) Partridge 1983
(l) Lukens 1984
(m) Cochnauer 1983
(n) Coon et al. 1977
(o) Oregon Department of Fish and Wildlife, unpublished data

Table A5d. Length-weight relationships for white sturgeon.

Region	Statement of growth rate
Sacramento River - California	
Kohlhorst et al. (1980)	$\log_{10} W = 3.348 \log_{10} TL - 5.927$ W=kg; TL= total length in cm
Brennan and Cailliet (1989)	$\log_{10} W = 2.98 (\log_{10} TL) - 5.21$ (males) $\log_{10} W = 3.36 (\log_{10} TL) - 6.04$ (females) W=kg; TL= total length in cm
Columbia R.- downstream from Bonneville Dam	
McCabe et al. (1989)	$\log_{10} W = 3.11 (\log_{10} FL) - 5.46$ W=grams; FL= fork length in mm
Columbia R.- downstream from John Day Dam	
Parsley et al. (1989)	$\log W = 3.10 (\log FL) - 5.425$ W=grams; FL= fork length in mm The Dalles Pool
Beamesderfer et al. (1989)	$W = (1.37 \times 10^{-6}) (FL^{3.37})$ W=grams; FL= fork length in cm The Dalles Pool
Parsley et al. (1989)	$\log W = 3.01 (\log FL) - 5.19$ W=grams; FL= fork length in mm Bonneville Pool
Beamesderfer et al. (1989)	$W = (1.83 \times 10^{-6}) (FL^{3.33})$ W=grams; FL= fork length in cm Bonneville Pool
Snake River - Idaho:	
Cochnauer (1983)	$W = (0.03 \times 10^{-6}) (TL^{3.6127})$ W=kg; TL=total length in cm C.J. Strike Dam to Bliss Dam

Table A5d (cont.). Length-weight relationships for white sturgeon.

Region	Statement of growth rate
<u>Fraser R. - British Columbia, Canada</u>	
Semakula and Larkin (1968)	$\log_e W = (3.13 \log_e FL) - 8.73$ (males) $\log_e W = (3.15 \log_e FL) - 8.79$ (females) W=lbs; FL= fork length in inches
Dixon (1986)	$\log_e W = (3.44 \log_e TL) - 14.33$ $\log_e W = (3.13 \log_e FL) - 13.35$ W=kg; TL and FL in cm Omineca region

Table A6. Estimated instantaneous annual mortality (Z), total annual mortality (A), instantaneous natural mortality (M), annual survival (S), fishing mortality (F), and exploitation (E) rates for white sturgeon.

Z	A	M	S	F	E	Citation
0.13-0.17	0.12-0.16	–	0.84-0.88	–	0.06-0.07	Kohlhorst 1980
0.11-0.30	0.10-0.26	–	0.74-0.90	–	0.02-0.12	Kohlhorst et al. 1991
–	0.39-0.40	–	0.56-0.61	–	–	Kreitman and James 1988 (91-102 cm)
–	–	–	–	–	0.16-0.35	Kreitman and James 1988 (all sizes Jun-Oct)
–	–	–	–	–	0.06-0.09	Nigro et al. 1988 (June-Oct. sport fishery)
–	–	–	–	–	0.29	Nigro et al. 1988 (July-Dec. sport fishery)
0.32	0.27	–	0.73	–	–	Cochnauer 1983 (ages 4-15)
0.06	0.06	–	0.94	–	–	Cochnauer 1983 (ages 16-30)
0.13	0.12	0.13	0.88	–	–	Lukens 1985 (ages 6-25) from data collected in the mid 1980s
0.43	0.35	–	0.65	0.30	0.24	Lukens 1985 (ages 10-20) from data collected in mid 1970s
0.219	0.197	0.089	0.800	0.130	0.12	Semakula 1963

APPENDIX B
Distribution, Habitat, and Abundance Information

Table B1. Morphometric characteristics of the mainstem Columbia River from Bonneville Dam to Chief Joseph Dam (Columbia River) and Lower Granite Dam (Snake River).

Dam location river mile	Reservoir	Distance (miles) Length	Shore line	Ratio	Surface area (acres) Reserv.	Orig. river	Ave. depth	Years built
Columbia River								
145.5	Bonneville	46.2	144.2	3.1	20,400	15,000	28	1933-38
191.7	The Dalles	23.9	76.0	3.2	11,650	6,016	28	1952-59
215.6	John Day	76.4	323.6	4.2	51,000	27,570	46	1958-68
292.0	McNary	61.0	237.2	3.9	38,800	23,138	35	1947-54
353.0	Unimpounded	44.0	156.0	3.5				
397.0	Priest Rapids	18.0	57.5	3.2	8,320	4,315	24	1947-54
415.0	Wanapum	38.0	94.0	2.5	14,720	6,950	49	1959-63
453.0	Rock Island	21.0	43.0	2.0	3,470	2,781	33	1928-33
474.0	Rocky Reach	42.0	93.0	2.2	9,800	4,710	44	1956-61
515.8	Wells	29.2	99.8	3.4	9,548	4,162	31	1963-67
545.0	Chief Joseph	52.0	108.0	2.1	7,800	4,601	66	1950-55
Snake River								
334	Ice Harbor	32						1961
366	L. Monumental	29						1969
395	Little Goose	37						1970
432	Lower Granite	39						1975

Table B2. Morphometric characteristics of the mainstem Columbia River upstream from Chief Joseph Reservoir and Snake River reservoirs upstream from Lower Granite Reservoir.

Dam location river mile	Reservoir	Distance (miles) Length	Shore line	Ratio	Surface area (acres) Reserv.	Orig. river	Ave. depth	Years built
Columbia River								
597	Grand Coulee	150	660	4.4	83,000	18,100	115	1933-41
Snake River								
571	Hells Canyon	22				25,000	68	1967
597	Oxbow	12						1961
609	Brownlee	57				15,000	98	1958
	Unimpounded							
	Swan Falls	--						1910
	Unimpounded							
494	C.J. Strike	--				7,500		1952
517	Unimpounded	30						
560	Bliss	6				254	43	1950
	Unimpounded	7						
573	Lower Salmon Falls	7				861	22	1932
580	Upper Salmon	6				810	4	
	Shoshone Falls							

Table B3. Estimates of the ratio of sublegal to legal fish in the lower Columbia River recreational fishery from 1982-1990; the minimum legal size was increased from 36 in (91 cm TL) to 40 in (102 cm TL) in 1990 (Melcher and King 1991).

Year	Ratio of sublegal to legal-sized sturgeon
1982	5.2 to 1
1983	4.3 to 1
1984	3.4 to 1
1985	2.8 to 1
1986	2.5 to 1
1987	3.3 to 1
1988	4.4 to 1
1989	9.0 to 1
1990	13.4 to 1

Table B4. The catch per unit effort (CPUE) observed for three size classes of white sturgeon taken on setline in the Bonneville, The Dalles, and John Day pools of the Columbia River in 1988, 1989, and 1990 (Beamesderfer, ODFW, pers. commun.).

Location (year)	CPUE (fish/setline day)		
	<90 cm FL	90 cm to 180 cm FL	>180 cm FL
Bonneville Pool (1989)	3.56	0.78	0.03
The Dalles Pool (1988)	1.23	1.03	0.09
John Day Pool (1990)	0.21	0.30	0.02

Table B5. Monthly estimates of the setline catch of sturgeon (fish/hook-hr) in the Snake River between Lower Granite and Hells Canyon dams from 1982-1984 (adapted from Lukens 1985).

	Fish/hook-hour		
Month	1982	1983	1984
April	0.008	--	--
May	0.006	--	--
June	0.031	0.015	0.031
July	0.019	0.006	0.024
August	0.015	0.005	0.011
September	--	--	0.005
October	--	--	0.012
Total	0.018	0.010	0.014

APPENDIX C
History of Fishing Regulations

Table C1. History of white and green sturgeon fishing regulations in the Sacramento-San Joaquin River system.

Year	Fishing regulation
1875-1901	Unregulated fishing, primarily commercial
1901	Fishing prohibited
1910	Fishing regulated, primarily commercial
1912	Fishing prohibited
1916	Fishing regulated
1917	Fishing prohibited
1954	Sport fishing only permitted, 40-in (102 cm) minimum length, 1 fish/day, year-round season
1956	Minimum size increased to 50 in (127 cm)
1963	Minimum size reduced to 40 in (102 cm)
1990	Minimum size increased to 42 in (107 cm), maximum size of 72 in (183 cm), gaffs prohibited for landing sturgeon
1991	Minimum size increased to 44 in (112 cm)

Table C2a. History of significant commercial regulations for white and green sturgeon in the lower Columbia River below Bonneville Dam.

Year	Commercial regulation
1897	WA had a closed season (March 1-Nov. 1) and a minimum size.
1899	OR had a closed season (March 1-Nov. 1); 48-in minimum size; Chinese gang (snag) lines prohibited.
1900s	Sturgeon allowed during any open commercial salmon gill-net fishery. Use of setlines allowed during gill-net seasons.
1950	6-ft maximum size limit.
1950s	Unlawful to remove head and/or tail prior to being received at premises of licensed wholesale fish dealer.
1975-85	Target setline fisheries of varying duration (1-9 months annually) and varying areas allowed outside of salmon gill-net seasons. These target fisheries were legislatively phased out (1983-85) by the Washington Legislature.
1987	Unlawful to disfigure or possess a disfigured sturgeon to the extent size cannot be determined.
1983-88	Target large-mesh gill-net fisheries established outside of salmon gill-net fisheries as replacement for setline fisheries. Season occurred in late January to mid-February throughout the lower Columbia River, and in 1986 from late July to early August in the estuary.
1989	Beginning of harvest rate management.
1989+	No target sturgeon commercial fishing. Sturgeon allowed as an incidental species, however, times and zones can be closed if sturgeon landings exceed salmon landings.

Table C2b. History of sport harvest regulations for white and green sturgeon in the lower Columbia River below Bonneville Dam.

Year	Sport harvest regulation
1940	No size limits. No daily limit except no more than 3 fish under 4 ft or 32 in dressed.
1942	No size limits. Daily limit of 5 fish; no more than 3 fish under 4 ft or 2 fish over 4 ft.
1950	30-72 in slot size limit. Daily limit of 5 fish; no more than 3 under 4 ft.
1951	Same slot size limit. Daily limit of 3 fish.
1957	Cannot remove head and/or tail in the field.
1958	36-72 in slot limit. Daily limit of 3 fish.
1962	Possession limit of 3 fish.
1984	Illegal to remove eggs from any sturgeon without retaining carcass in the field or in transit.
1986	36-72 in slot limit. Daily limit of 2 fish; weekly and possession limit of 6 fish; for Oregon anglers, an annual limit of 30 fish. Sturgeon tag required of Oregon anglers. Gaffing prohibited and single-point hooks required of Washington anglers.
1988	Sturgeon tag required of Washington anglers.
1989	Beginning of harvest rate management. 40-72 in slot limit; annual limit of 15 fish in Washington.
1990	Gaffing prohibited and single-point hooks required of Oregon anglers. Hooks must be barbless for all anglers. Annual limit of 15 fish established for Oregon anglers.
1991	40-72 in slot size. Daily limit of 2 fish (only 1 <48 in and 1 $\geq$ 48 in).

Table C3a. History of white sturgeon commercial regulations in the middle Columbia River between Bonneville and McNary dams (Zone 6).

Year	Commercial regulation
Late 1800s - 1970s	Same as lower Columbia (see Appendix Table C2a).
- 1970	36-72 in sturgeon allowed year-round for treaty Indian subsistence purposes.
1976-present	Target sturgeon setline fisheries of varying duration (1-10 months annually) in all of Zone 6.
1988-present	Annual catch guidelines for Zone 6 adopted by SMTF. Setline fisheries reduced and sales of sturgeon prohibited during some salmon gill-net fishing weeks or seasons.
1991	Beginning of harvest rate management under SMTF. Tribal 1991 catch guideline of 1,650 fish (100 fish in John Day Pool, 300 in The Dalles Pool, and 1,250 in the Bonneville Pool).

Table C3b. History of sport harvest regulations for white sturgeon in the middle Columbia River between Bonneville and McNary dams (Zone 6).

Year	Sport harvest regulation
Prior to 1988	Same as lower Columbia sport regulations (see Appendix Table C2b).
1988	Beginning of management by SMTF. 40-72 in slot limit.
1988-90	Except for slot limit, same sport regulations as lower Columbia (see Appendix Table C2b).
1991	Beginning of harvest rate management by the SMTF. 1991 catch guideline of 1,550 fish (100 fish in John Day Pool, 100 in The Dalles Pool, and 1,350 in the Bonneville Pool). Above The Dalles Dam, slot limit reduced to 48-66 in and bag limit reduced to 1 fish/day.

Table C4. Summary of fishing regulations influencing sturgeon in the Columbia River Basin and its tributaries upstream from Chief Joseph Dam.

Year	Regulation
Washington	
1983	2 fish per year 36-72 in long.
1988	Sturgeon tag implemented. 40-72 in size slot limit.
1989	Annual bag limit 15 fish.
1990	Regulations for area upstream from McNary Dam to Oregon and Washington border: Open all year; minimum size limit=40 in; maximum size limit=72 in; daily bag limit 2 fish per day.
	Regulations upstream from OR and WA border to Canadian border: Open all year, except for the Hanford Reach (that is closed from 10/23-6/15); minimum size= 48 in; Maximum size=66 in); daily bag limit=1 fish per day.
1991	Regulations for The Dalles Dam upstream to Canadian border: Open all year, except for the Hanford Reach (that is closed from 10/23-6/15); minimum size= 48 in; Maximum size=66 in); daily bag limit=1 fish per day.
Idaho (Kootenai River)	
1943	All commercial harvest in Idaho banned.
1944	2 in possession; no yearly limit.
1948	1 setline; 1 in possession.
1949	1 setline; 1 in possession; minimum size 30 in.
1955	1 setline; 1 in possession; minimum size 40 in.
1957	1 setline; 2 per year; 1 in possession; minimum size 40 in.
1960	1 setline; 2 per year; 1 in possession; 36-72 in length restriction.
1979	2 per year; 1 in possession; 36-72 in; permit required.
1983	Setlines prohibited; season July 1-December 31; 1 per year; 36-72 in.
1984	Catch and release only; open all year.
1989	Fishermen's log program.
Montana (Kootenai River)	
1957	Setlines permitted for burbot (ling) only.
1968	Setlines permitted for sturgeon February 15-June 30.
1973	6 setlines with 6 hooks per line permitted February 15-June 30; 2 per year; 40-72 in.
1975	No setlines; 2 per year; 40-72 in.
1979	It became illegal to fish for white sturgeon.

Table C5. Summary of Idaho's white sturgeon sport harvest regulations for the Snake River upstream from Lower Granite Dam.

Year	Sport harvest regulation
1943-1947	2 in possession; no yearly limit; commercial fishing prohibited.
1948-1949	1 in possession; no yearly limit; 1 setline permitted.
1950-1954	1 in possession; 30-in minimum length; no yearly limit; 1 setline permitted.
1955	1 in possession; 42-in minimum length; setline allowed except in Hells Canyon.
1956-1960	1 in possession; 40-in minimum length; 2 fish per year.
1961-1963	3 in possession or annually in boundary waters, 2 fish elsewhere, 36-72 in.
1964-1969	1 in possession, 36-72 in; 2 fish per year.
1970	Catch and release for entire Snake River.

APPENDIX D
Fish Nutrition Requirements

Table D. Nutritional requirements of juvenile white sturgeon reared in a culture facility.

Dietary component	Source	Ration	Citation
Choline	most forms; found in lecithin	0.17-0.31% choline or 8% lecithin in diet	Hung 1989
Carbohydrate	maltose and glucose	optimum ration not known (in contrast to the less usable sucrose or lactose)	Hung et al. 1989b
Carbohydrate		3.7 g digestible/kg/day	Kaushik et al. 1989
Crude protein	casein type	300 g for 145 g fish (40%)	Moore et al. 1988
Crude protein		36.5-40.5% per day for fish 145-300 g	Moore et al. 1988
<u>Control Experimental Diet</u>			
		38% crude protein 12.9% lipid 8% soy lecithin	Stuart and Hung 1989
<u>Recommended Diet</u>			
		0.17%-0.32% choline 40% crude protein; casein or casin (62%); wheat(30%); egg white(8%) Carbohydrate (ration not given, but OK @ 27%); maltose or glucose	Hung 1989

APPENDIX E
Research-Needs Matrix for the Columbia Basin by Fickeisen (1985a)

Table E. White sturgeon research priorities for the Columbia River Basin (Fickeisen 1985a).

River reach	Population abundance	Age composit., growth, & surv.	Reproduct. biology	Early life history	Food habits	Physical habitat req.	Map & model avail. habitat	Extent of movement
Below Bonneville Dam[1]	low	low	low	low	low	high	moderate	low
Bonneville-McNary	high	high	high	high	low	high	moderate	high
McNary-Priest Rapids/ Ice Harbor	high	high	high	high	low	moderate[2]	low	high
Priest Rapids- Chief Joseph	moderate[2]	moderate[2]	moderate[2]	moderate[2]	low	moderate[2]	low	moderate[2]
Columbia above Chief Joseph	moderate[2]	moderate[2]	moderate[2]	moderate[2]	low	moderate[2]	low	moderate[2]
Kootenai River	high	high	high	high	low	moderate[2]	low	high
Ice Harbor- Lower Granite	moderate[2]	moderate[2]	moderate[2]	moderate[2]	low	moderate[2]	low	moderate[2]
Lower Granite- Hells Canyon	low	low	high	high	low	high	moderate[2]	low
Above Hells Canyon	low	low	high	high	low	high	moderate[2]	low

[1] A Dingell-Johnson project is in progress in this reach.

[2] Would be higher in the long term.

C-052127